A TAXONOMY BASED ASSESSMENT METHODOLOGY FOR

SMALL AND MEDIUM SIZE MANUFACTURERS

By

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The need for small and medium size manufacturing enterprises (SMEs) to have access to unbiased advice on best practices and related improvement approaches has been well established. However, this need was not found addressed very effectively in the research literature. Current practice consists of consultants offering assessment tools which have the veneer of objectivity, but in reality only highlight the need to purchase their canned solutions.

In response, this research attempts to synthesize previous research results and other published assessment methodologies into a taxonomy based assessment methodology (TBAM) which targets the delivery of recommendations aimed at improving the performance of the manufacturing enterprise. The assessment methodology which emerges from this research draws upon two taxonomies, the Manufacturing Enterprise Taxonomy (MET) and the Production System Taxonomy (PST). The MET was developed as a direct result of this research and the PST was developed by a modest modification of previously published best practice taxonomy.

The TBAM approach was piloted using three different SMEs in order to obtain feedback from the field. As a result TBAM was enhanced using feedback obtained from these three pilot cases. In addition, a review panel process was developed so that a third party review was made of the methodology and its application within the case studies. The review panel was comprised of senior managers which have substantial experience in leading improvements across small and medium size manufacturers. Also, concerns about reliability and validity were addressed and a preliminary set of measures was obtained and evaluated. Based upon this preliminary technique, the validity and reliability results associated with the TBAM approach appear promising.

Key words: assessment, taxonomy, manufacturing,

DEDICATION

This work would not have been possible without the love, devotion, endurance, and encouragement of my wife Marsha. I am forever thankful to God's gracious providence in providing me with such a wonderful life partner. You have supported and sacrificed for me across the almost 20 years of marriage in ways far more than I deserve.

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Finally, any contribution resulting from this work is reflected to Him - who is the way, the truth, and the life.

"You are the author of knowledge; you can redeem what's been done." - The Newsboys

"And whatever you do, in word or deed, do all in the name of the Lord Jesus, giving thanks to God the Father through Him." – Colossians 3:17

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CHAPTER 1

INTRODUCTION

1.1 Research Motivation: Importance of Manufacturing

The United States, despite recent struggles, remains the world's leading producer of manufactured goods.[1] It is difficult to underestimate the importance of manufacturing to the economic health of the nation. The United States' manufacturing segment, if it were a country, represents the world's 5th largest economy.[2] In addition, the nation leads all countries in the absolute level of labor productivity, which according to one government report has enabled the United States to gain a competitive advantage over its trade partners, despite higher wages and benefits paid to American workers.[3]

While manufacturing has contributed greatly to an increased standard of living, this sector has recently experienced a level of unprecedented challenges and changes. The last economic downturn hit manufacturing particularly hard. During a twelve quarter stretch between 2001 and 2003, manufacturing output fell 6% and employment dropped by 2.5 million.[4]

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[1] Manufacturing in America: A Comprehensive Strategy to Address the Challenges to U.S. Manufacturers, United States Department of Commerce, Washington, D.C., January 2004, pg. 7.

[2] Ibid, pg. 7

[3] Ibid, pg. 15

[4] Ibid, pg. 7

Overseas competition, aided by international trade agreements, has had a dramatic impact, both positively and negatively, on manufacturing operations. In certain industries (e.g., furniture, clothing & apparel, consumer electronics), the domestic job loss has been staggering. Conversely, the automotive industry has witnessed an unmatched level of investments from foreign owned firms in domestic manufacturing operations (e.g., Nissan, Mercedes, Toyota, BMW).

During the last 10 years, advances in information technology have significantly impacted the structure of manufacturing operations; traditional jobs and processes have become obsolete, while new work processes and jobs have emerged. A recent report by the United States Department of Commerce observed "the dramatic expansion of computing power and its application to an ever greater range of tasks in the business environment is, without a doubt, the single most powerful change affecting manufacturing today".[5]

Finally, the maturing of improvement initiatives (e.g., lean manufacturing and Six Sigma) has made enormous contribution to the re-design of manufacturing operations in terms of cost effectiveness, quality, and timeliness. As one industry sage commented "these techniques are no longer on trial, but our ability to apply them is".[6]

Other trends are present, and should not be ignored, when surveying the American manufacturing landscape. These include, but are certainly not limited to, increased environmental and safety regulations, outsourcing of engineering and professional support, changes to cost accounting methodology, increasing consumer demand, greater product diversity, and shorter product lifecycles.

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5 Ibid, pg. 22

6 Interview with Tommy Jamison, Vice President of Manufacturing, Mueller Industries, August 13, 2005.

1.2 Challenge of Smaller Manufacturers

Clearly, manufacturing firms operating in today's environment face a myriad of challenges in order to be successful. This task is particularly difficult for the nation's smaller manufacturers. These firms often either do not have sufficient understanding of or access to the resources, technologies, and management practices needed to meet these challenges. Data analyzed several years ago and available from the U.S. Census Bureau indicate a pronounced gap in productivity between large and small manufacturers. Figure 1.1 shows the difference between size of manufacturer and productivity, as measured in terms of dollar value per employee from 1967 through 1997.[7] While this data is admittedly dated, nevertheless a clear gap can be observed between large and small manufacturers. As shown in the figure below, the gap was relatively constant until the early 1990's. Since 1992 the gap steadily increased. In fact, from 1992 through 1997 the growth in productivity was 30% less for SME's (i.e., small manufacturing enterprise) than for larger manufacturers.

According to a recent report published by the Department of Commerce, "small manufacturing firms face huge challenges in this transforming world. Pressures to rapidly introduce new products and technology, reduce costs, and increase quality leave many small firms struggling to survive".[8] This report also noted that that while these challenges are daunting, small manufacturers have a great opportunity to increase their performance.

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[7] Panel Report of National Academy of Public Administration for the U.S. Department of Commerce, The National Institute of Standard and Technology's Manufacturing Extension Partnership Program, Report 1: Re-examining the Core Premise of the MEP Program, September 2003, pg. 7.

[8] Ibid, pg. 1

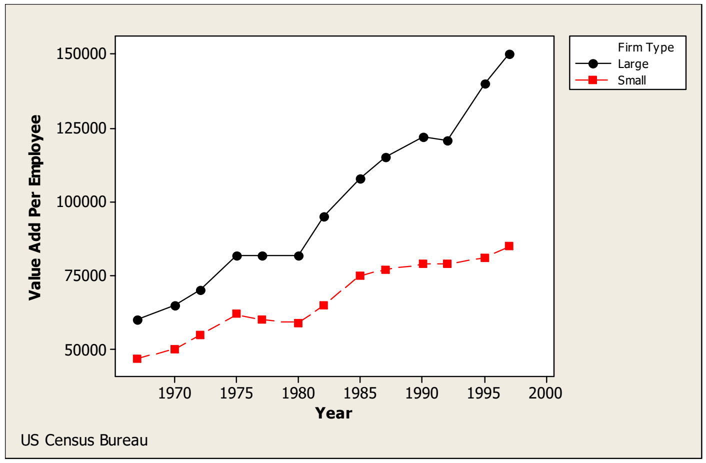

Figure 1.1 Productivity Gap: Large and Small Manufacturers[9]

U.S. Department of Commerce defines "small and medium size manufacturers", often referred to as small manufacturing enterprises (SME's), as plant sites that employ less than 500 people. Economic data provides ample evidence regarding SME's importance to the American economy. SMEs are responsible for about 7% of the country's GDP and employ 7 million people. In addition, SMEs account for 95% of all manufacturing establishments, responsible for over 50% of the value add in manufacturing, and comprise over 1/3 of the total value of exported products.[10]

Over a decade ago, the National Research Council (NRC) in their landmark report titled Learning to Change: Opportunities to Improve the Performance of Smaller Manufacturers documented the existence of the following five major barriers to enhanced SME performance.

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[9] The Manufacturing Extension Partnership: Delivering Measurable Returns to its Clients, January 2001, pp. 1.

[10] Ibid., pg. 1

- B1: Disproportionate burden due to regulatory environment.
- B2: Unfamiliarity with changing technology, production techniques, and business management practices.
- B3: Isolated and too few interactions with others in a similar condition.
- B4: Difficulty in obtaining high quality, unbiased advice and assistance.
- B5: Difficulty in obtaining needed operating capital and investment capital.

This report alarmingly concluded that the nation's SMEs were "operating far below their potential; their use of modern manufacturing equipment, methodologies, and management practices is inadequate to ensure that American manufacturing will be globally competitive".[11]

A more recent 2003 report sponsored by the Department of Commerce concluded that while evidence of each of these barriers still exists, two previously identified barriers remained major concerns (i.e., B2 and B4).[12] This report also identified the emergence of the following new barriers to SME performance.

- Increasing competition from low cost countries.
- Explosion of the availability of information and access to information technology.
- Insufficient access to skilled knowledge workers
- High cost of providing health insurance.

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[11] Manufacturing Studies Board, Commission on Engineering and Technical Systems, Learning to Change: Opportunities to Improve the Performance of Smaller Manufacturers, National Research Council, National Academy Press, 1993.

[12] Panel Report of National Academy of Public Administration for the US Department of Commerce, NIST's Manufacturing Extension Partnership Program, Report 1: Re-examining the Core Premise of the MEP Program, September 2003, pg. 16.

Of particular interest to this research is the long standing difficulty that SMEs have in "obtaining high quality, unbiased advice and assistance" and in general their "unfamiliarity with changing technology, production techniques, and business management practices." These performance barriers are particularly difficult in the global, rapidly changing, highly competitive environment in which small manufacturers compete.

There has been little published work which focuses specifically on the needs of smaller manufacturers. This is despite the findings of the National Research Council (1993), which clearly document the importance of SME's to the nation's manufacturing competitiveness. Confirming this result, one of the more recent publications noted "Despite the widespread recognition of the importance and significant contribution of SMEs, research on SMEs remains scarce."[13]

1.3 Research Problem

Some consultants advocate "assessment" tools which have the veneer of objectivity, but in reality, only highlight the need for manufacturers to purchase their "canned" solutions. Larger manufacturers have the staff resources to "rationalize" these approaches and facilitate the best fit within their organizations. However, SMEs, generally with little staff support, are susceptible to settling for canned approaches. This susceptibility may be inferred from the second barrier presented in NRC's 1993 report ("unfamiliarity with changing technology, production techniques, and business management practices"). Several manufacturing researchers have published similar sentiments. For example, Stewart (1995) observed "People who want quick results too easily

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[13] Sum, C.C., Kow, L.S., Chen, C.S., "A Taxonomy of Operations Strategy of High Performing Small and Medium Size Enterprises in Singapore", 2004, International Journal of Operations and Production Management, 2004, Vol. 24, No. 3, pp. 322.

believe people who promise them."[14] Also, Stoddard and Davis (1999) noted similarly "many of the popular fads in manufacturing work well in certain situations … the problem is canned solutions are not holistic solutions".[15] Finally, the problem is summed up nicely by Hopp and Spearman (2000) who state the following. "Each successive approach to manufacturing management – scientific management, operations research, MRP, JIT, TQM, BPR, ERP, … has been sold as the solution. Each one has disappointed us, but we continue to look for the technological silver bullet to save American manufacturing. When will we learn? Manufacturing is complex, large scale, multi-objective, rapidly changing, and highly competitive. There cannot be a simple, uniform solution that will work well across a spectrum of manufacturing environments." [16]

The core problem this research addresses is the difficulty that SMEs have in "obtaining high quality, unbiased advice and assistance" which the NRC has identified as a major barrier to enhanced SME performance. This research argues that a barrier to addressing this problem is the lack of a recommendation oriented assessment approach that attempts to objectively evaluate the manufacturing firm form an overall enterprise perspective. The literature review reveals that this research problem has been largely ignored by the academic literature. However, related published work provides a rich context from which to explore, synthesize, and apply to the assessment problem. The Figure 1.2 summarizes the motivation for this research.

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[14] Stewart, T. A., "Review of Fad Surfing in the Boardroom, by E.C. Shapiro", Fortune, 132(10). pg. 162

[15] Stoddard, Charles, Davis, Dale, Running Today's Factory: A Proven Strategy for Lean Manufacturing, 1999 Hanser Gardner Publications, Cincinnati, OH., pg 15.

16 Hopp, Wallace, Spearman, Mark, Factory Physics: Foundations of Manufacturing Management, Second Edition, 2001, Irwin McGraw-Hill, pp. 182.

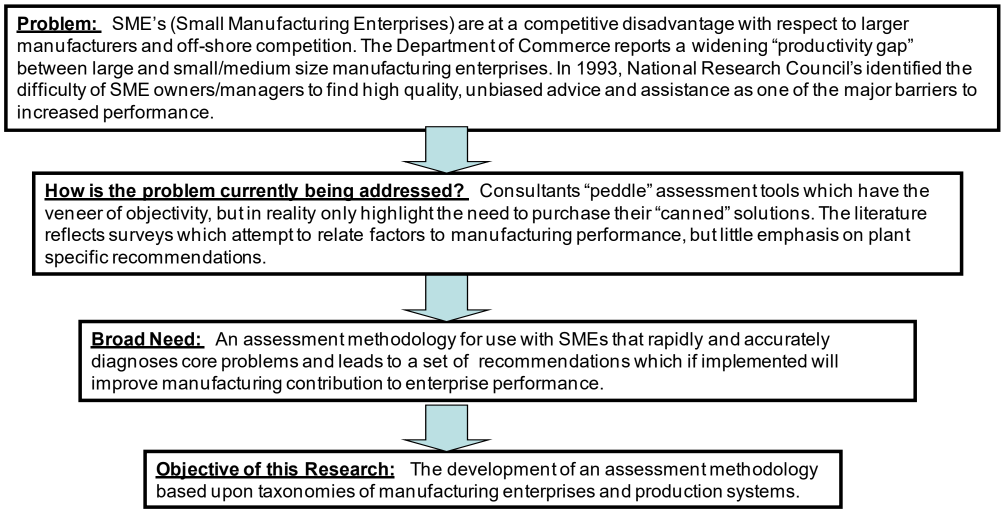

Figure 1.2 Research Motivation

This research addresses the following problem statement:

> There is not a consensus among practitioners concerning how to perform a more objective assessment of small to medium size manufacturing enterprises. No published work has been found which either develops a theoretical framework or provides a methodology for the assessment problem. This research provides a theoretical framework that enables practitioners to bridge the gap between research findings and the needs of manufacturers.

Therefore, the objective of this research is to develop an assessment methodology based upon taxonomies of the manufacturing enterprises and production system best practices.

1.4 Research Approach

Since the research literature does not fully address the specific problem of manufacturing assessments, the literature gives little guidance into how this problem should be approached. Most of the published work focuses on factors which influence the performance of manufacturing enterprises. Many of these publications rely upon evidence obtained from surveys, where theoretical constructs are empirically tested. These studies utilize inductive reasoning (i.e., arguing from particular sample evidence to general principles). Statistical inferences are made in order to identify factors that influence performance based upon sample evidence. Since the objective is to extract evidence from actual manufacturing firms, these studies are inherently descriptive. The conclusions derived from these studies are general constructs, perhaps loosely defined as manufacturing "truisms." Of course, these studies are needed so theoretical concepts can be validated and/or modified based upon actual data. The current approach is summarized in Figure 1.3.

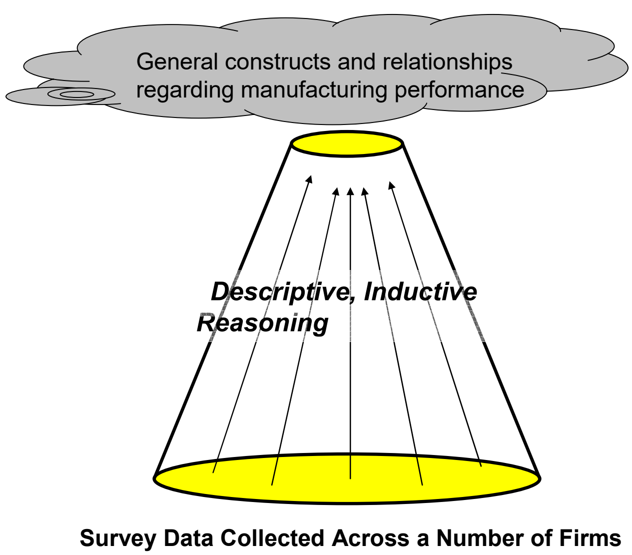

Figure 1.3 Current Approach within the Literature

The types of conclusions which one draws from these studies are often vague, conflicting, and at times counter-intuitive. Even skilled practitioners are left wondering how these conclusions are best deployed within a particular manufacturing environment. No framework was found in the literature which allows the growing body of knowledge within the field of operations management to be categorized, classified, and retrieved. If such a framework were developed, it would enable researchers to progress toward the development of an objective, unbiased assessment methodology which results in recommendations targeting improved manufacturing performance. This type of reasoning is inherently deductive (i.e., arguing from general principles to specific) and is fundamentally prescriptive. This research relies heavily upon this approach and is illustrated graphically in Figure 1.4.

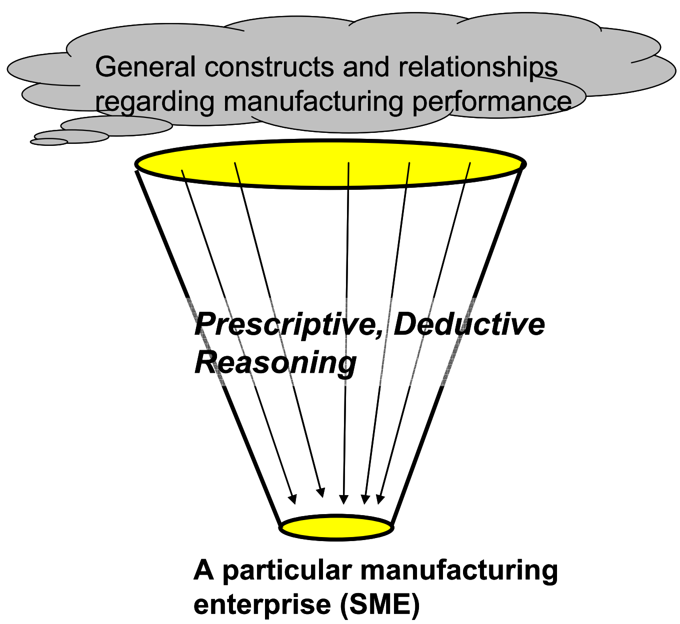

Figure 1.4   Fundamental Approach of this Research

The current research emphasis has largely ignored the problem about how to deploy these results for a particular manufacturer. The problem of determining how to best deploy these general constructs for a specific firm at a particular point in time is a fundamental engineering question. Of course, basic to the engineering profession is the challenge of applying general constructs and principles to work specific problems. Similarly, the assessment challenge is to determine how to formulate recommendations rooted form a thorough, yet rapid evaluation of the SME.

Also, this research proposes that the assessment is the "dual" of the typical survey based studies common within the literature. While surveys attempt to develop broad associations and validate constructs regarding manufacturing performance across a wide number of firms, the assessment attempts to "survey" general principles and constructs and deploy recommendations which target enhanced performance within one firm. If this duality holds, then an intriguing research question is what new sets of analytical tools need to be developed or adopted in order to work effectively in this paradigm. Obviously, fully answering this question is beyond the scope of this research. However, this research provides a framework for the assessment problem.

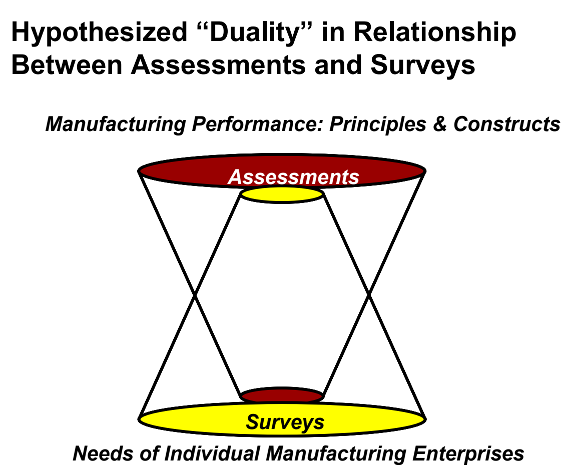

Figure 1.5 Illustration of Duality between Assessments and Survey

This research provides the framework and a first generation assessment methodology which is targeted at addressing the need of SMEs for obtaining "unbiased advice."

This methodology is based on the premise that similar types of manufacturing enterprises will tend to have common types of core problems which will lead to similar types of recommendations. The methodology utilizes a Manufacturing Enterprise Taxonomy (MET) that enables the assessor to determine where the firm "fits" within the manufacturing landscape. In addition, a prototype Production System Taxonomy (PST) is developed that characterizes the "solution space" from which recommendations are generated. The assessment tool assists the assessor in mapping recommendations from the PST. This is illustrated in the Figure 1.6.

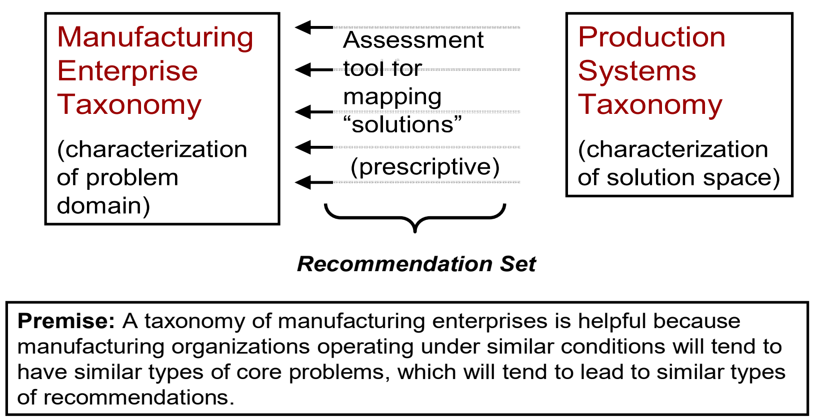

Figure 1.6 Approach to The Research Problem

Therefore, the research approach is to:

- Evaluate the existing literature on manufacturing performance and related topics, and summarize key findings and linkages.

- Develop a manufacturing enterprise taxonomy (MET), drawing upon findings from the literature.
- Develop a production systems taxonomy (PST), drawing upon findings from the literature.
- Validate the taxonomies through structured interaction with industry experts.
- Develop a new assessment methodology that draws upon the MET in order to properly characterize the firm and utilizes the PST to develop an effective set of recommendations.
- Pilot the new methodologies using case studies and refine based upon feedback.

It is important to recognize that the working definition of assessment includes both an appraisal and a recommendation aspect. The appraisal component focuses on understanding the current performance, major challenges, root causes, and current approaches that a firm is using to compete. The recommendation aspect focuses on the development of a set of recommendations which target improved performance of the manufacturing firm at the specific point of time the assessment is conducted.

Therefore, the objective of this research is to develop an assessment tool that rapidly and accurately diagnoses core problems facing an enterprise and develops a set of powerful recommendation; which, if implemented, results in improved performance. The accomplishment of this objective involves the development of an assessment methodology, which draws upon taxonomies of manufacturing enterprises and best practices. The objective of the methodology is to develop a set of recommendations which stem from this rapid and thorough review of an SME.

The methodology is piloted using a case study approach. This approach enables documented feedback from the field and a third party evaluation of both the cases and the methodology.

1.5 Taxonomy Development

The word taxonomy is derived from the Greek word "taxis" which means arrangement and "nomos" meaning law; literally, "law of arrangement." According to one definition, taxonomy is the science of classification according to a predetermined system, with the resulting catalogue used to provide conceptual framework for discussion, analysis, or information retrieval.[17] Within a taxonomy items are classified according into groups (i.e., taxons) and into sub-groups (i.e., "taxa").

1.5.1 Manufacturing Enterprise Taxonomy

The objective of the manufacturing enterprise taxonomy (MET) is to determine where the SME fits within a classification scheme. This scheme is derived based on experience, findings from the research literature, and other published assessment methodologies. This taxonomy is not intended to lead to an exhaustive depiction of a manufacturing firm, but to an overall description of key elements, useful from the perspective of a manufacturing assessment. The premise is that firms operating under similar conditions will tend to have similar types of problems. This taxonomy's usefulness is based on the premise that if we can identify where subsequently a SME fits within the MET, this will assist in rapidly focusing on core problems, and recommendations.

A brief review of many of the issues the MET addresses is provided below with a more thorough treatment found in chapter three.

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[17] Reference obtained from **www.whatisit.com**, accessed on November 14, 2005.

Properly couching the business environment provides useful insight on the context under which an SME must operate. Key aspects include an evaluation of the regulatory environment, market conditions, an appraisal of external threats, and the measure of business seasonality. Understanding of both product and process attributes and their interaction is also necessary. This is clearly demonstrated by the numerous publications that reference the work of Wheelwright and Hayes during the late 1970's through the mid 1980's. Product characterization includes such items as volume, lifecycle, complexity, and variety. Similarly, process characterization includes such issues as level of integration, complexity, layout, and capacity. Also included are the attributes such as plant structure (e.g., Goldratt's VAT classification), nature of bottleneck (stationary or wandering), and type of quality system.

The firm's current approach to managing human resource capital is also critical as both the literature and experience indicate. While this subject is complex and multi-faceted and a thorough treatment is beyond the scope of this research, it nonetheless must be included because it plays a critical role in performing an accurate assessment. Also, elements which describe the financial health of a firm are addressed. For example, a number of undesirable effects across an organization may ultimately be related to the fact that the firm is operating under severe working capital restrictions. Again, a thorough treatment of this element is out of scope, but its importance cannot be ignored.

Finally, MET includes performance measures and connection to overall strategy. It is clear from the literature that measurements must include non-financial as well as financial measures.

1.5.2 Production Systems Taxonomy

The purpose of the Production Systems Taxonomy (PST) is to characterize and structure the "solution space" in such a way that recommendations are selected that address core problems stemming from the assessment. Generally little work has been done to structure such a solution space. In fact, Sipper & Bulfin note the following "We make a strong statement here by claiming that management theories and techniques that have been used for a long time … need to be updated. The environment from which they emerged has been totally transformed. On the other hand, the substitute theories are in a state of flux. Many ideas, concepts, and techniques have been proposed but have yet to become a unified theory of production management."[18]

Clearly, this is a rather daunting challenge. However, an initial PST is developed, using a modest modification to previously published work. This version of the PST was developed for this research is adequate. It is hoped that future researchers will continue to enhance this structure.

1.6 Assessment Methodology

The major objective of this research is to develop an assessment methodology that targets the delivery of effective and implementable recommendations for particular small to medium size manufacturing firms. This is accomplished through the development of a Taxonomy Based Assessment Methodology (TBAM). The role of taxonomies, or simply classification schemes, is to provide a measure of objectivity to the problem of developing an unbiased set of recommendations for SMEs. Clearly, the problem of rapid and accurate assessment of a SME

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[18] Sipper, Daniel Bulfin, Robert Production: Planning, Control, and Integration, 1997 McGraw-Hill, pg. 25.

based on an assessment team spending limited time on-site is a highly subjective problem. The assessor's skill remains of critical importance. However, the challenge of this research is to bring a greater degree of objectivity, or at least to define more clearly the required subjective judgments. This was not found in the literature and thus a major contribution of this research. This approach is more fully developed in chapter three, but a brief overview of the assessment methodology is provided and is illustrated in Figure 1.7.

The TBAM methodology is designed so that observations, findings and recommendations are clearly and logically defined within the context of a field assessment of a manufacturing enterprise. This is accomplished through the linking of three foundational elements: evaluation, diagnosis, and prescription. The TBAM approach draws upon the use of taxonomies in order to structure the assessment process with the goal of bringing a greater degree of clarity and objectivity within a very subjective problem domain. Two different taxonomies are used, the manufacturing enterprise taxonomy (MET) and the production system (PST). The MET provides the assessor an on-site survey instrument in order to provide a logical structure from which to evaluate and probe issues within a company. The PST is a modest modification to a taxonomy of best practices previously published by Bolden[19]. The PST serves as a basis for selecting relevant prescriptions (or candidate best practices), which in turn helps guide the formulation of alternatives. The pivotal component of the assessment methodology is the diagnosis stage, which serves to connect evaluation with prescription. In particular, the use of the Current Reality Tree links the "undesirable effects" (i.e., UDEs) identified during evaluation with a limited set of root

[19] Bolden, Richard, Waterson, Patrick, Warr, Peter, Clegg, Chris, and Wall, Toby, "A New Taxonomy of Modern Manufacturing Practices", International Journal of Operations and Production Management, Vol. 17, No. 11, 1997, pp. 1126 – 1130.

causes which is used as the basis for selecting prescriptions from a larger set of possible prescriptions defined within the PST.

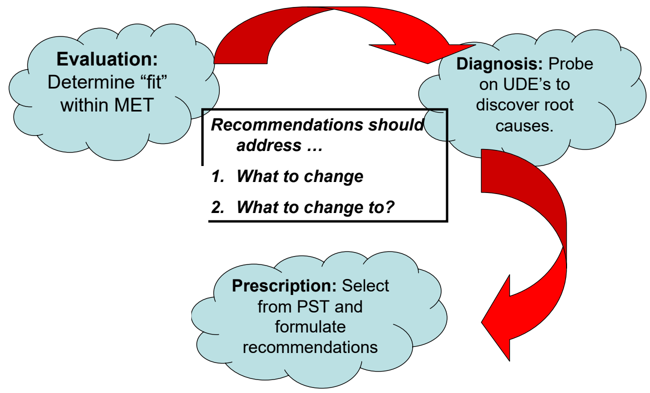

Figure 1.7 Overview of the Assessment Methodology

It is argued in this research that the TBAM approach shows promise for achieving the following characteristics, which are particularly important for the assessment methodology to be well received by SMEs. .

- The assessment must be rapid and unobtrusive. The goal is to perform the onsite evaluation survey within one to two days.
- The targeted completion period for the assessment is one week.
- The assessment documentation needs to logically communicate the rationale for the recommendations.
- The assessment should be thorough, involving an enterprise-wide perspective.

1.6.1 Validation of Assessment Methodology

The vision is to develop a methodology which is both accurate and in some sense repeatable. Therefore, this research posits definitions of validity and reliability within the special context of manufacturing assessments. In addition, this research develops a set of rapid and responsive measures, which taken collectively provide some indications regarding the validity and reliability.

Validity is concerned with how effective the recommendations are in terms of driving enterprise-wide improvements. Reliability results from concerns about the repeatability of the methodology assuming qualified assessors.

The development of specific recommendations by qualified assessors remains subjective and dependent upon the assessors experience, background, and judgment. Also both experience and literature suggest there are many paths leading to enterprise-wide improvement. Therefore, in the opinion of this researcher issues of validity are more important reliability, particularly for new and emerging approaches like TBAM. It should be noted that foundational levels of reliability should be attained.

Generally, the assessment methodology and the taxonomies upon which the methodology is based will be validated in the following ways.

- Literature – Since some aspects of the MET and PST were developed prior to the literature review, therefore the literature review will be used to re-enforce some aspects of the taxonomy.

- Case Study – the application of TBAM across the three cases has resulted in obtaining feedback from the field confirms some aspects and provides the basis for modifying the methodology. These pilot case studies are presented in chapter four.

- Review Panel – This involved the presentation of the case studies to a third-party panel of experts. This panel reviewed the cases presented and were asked to make judgments about both the case and the overall methodology. The panel's decisions about the case were analyzed and measures of validity and reliability were collected. This is described in chapter five.

1.6.2 Case Study and Panel Review Approach

Once the TBAM was completed, the approach was piloted in the field with three different SMEs. Each of the three cases were documented using a common format. The resulting cases were presented to a review panel, comprised of senior leaders with substantial experience leading SMEs. The review panel feedback was evaluated in order to provide some indication of the methodology's usefulness. The resulting case studies are presented in chapter four. The analysis of data collected from the review panel is found in chapter five.

The objective of the piloting activity is to obtain feedback from actual use with SMEs. As a result, the overall methodology indicated some level of validation from being successfully applied in three different companies with very different manufacturing environments.

Of course, critical to the success of the pilot is the perceived willingness of the SME to participate in the process. Early discussions were conducted in order to determine the openness and willingness of the firm to participate. All three participating firms met the criteria of being small to medium size manufacturing enterprises (i.e., less than 200 employees on-site). These companies were from a cross section of industries including telecommunications, electrical power components, and precision optics. The names of these firms remain confidential and are referred to within the research as Alpha, Beta, and Gamma.

Also since cases are not selected randomly, statistical inference is not appropriate, based upon across- client data. However, the use of a common case study format begins to allow for proper data to be captured where ultimately some level of inferences could be made across cases.

Clearly, researchers have identified numerous purposes for case studies. These purposes include "to chronicle events, to render, depict, or characterize; to instruct; and to try out, prove or test."[20] One researcher stated that case studies are particularly appropriate in situations where attitudes and behaviors can best be understood in their natural setting.[21]

Therefore, the case study approach is particularly well suited for the piloting of TBAM. These pilots must occur under field conditions. Thus, a common case study format was used, which enables both analysis within a case, and over time, analysis across cases.

Therefore, the purpose of case study methods, in this research, is not to generalize about issues surrounding manufacturing performance, but to obtain targeted feedback regarding the overall assessment methodology. The objective is to thoroughly document pilot results so the overall methodology can be refined and improved over time. The general format for the documentation of each case study, found in Table 1.1, was based generally upon the approach used by Cox and Spencer, 1998.[22]

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20 Cox, James F. and Spencer, Michael S., The Constraints Management Handbook, 1998, CRC Press, Boca Raton, FL., pg. 133.

21 Ibid, pg. 133

22 Ibid, pg. 133

Table 1.1

Case Study Format

I.	Introduction to Company	
II.	Assessment	
	a.	Evaluation
	b.	Diagnosis
	c.	Prescription
III.	Client's Level of Receptivity	
IV.	Critique of Methodology	

Since this research involves interaction with human subjects both at a case study level and for the panel review session, a Institutional Review Board proposal was developed for ensuring the ethical protection of human subjects used in this research. This proposal was submitted to Mississippi State University's Office of Regulatory Compliance. The proposal was approved prior to the commencement of the research (i.e., the docket number for this project was #07-068).

1.7 Research Limitations

It is beyond the scope of this research to develop the ultimate assessment tool for small manufacturing firms. Therefore, the assessment methodology this research developed has limitations and certainly should not be construed as the missing "silver bullet" that will solve all the ills of small manufacturing enterprises.

The scope of this research ends with the development of recommendations. Therefore, a limitation of this work is that the assessment deliverable is a set of recommendations which target enhanced performance, this should not to be confused with actual improvement. Other research needs to be conducted focused more on issues of implementation and execution.

It should be noted that this does not mean that the hard and difficult work of implementation is unimportant. In fact, experience indicates that most failures within SMEs come not so much from improper recommendations, but from the failure to implement well. In order to achieve actual improvements, strong leadership, effective project management, and ongoing problem solving skills are essential.

Additionally, the proposed assessment methodology does not produce a "once for all" set of recommendations. Since the manufacturing environment is constantly changing, recommendations provided at one point in time, may not be appropriate later. Another important limitation of this approach is that participants are assumed to complete the assessment survey and probing questions in an open and honest manner. Qualifying the veracity of the responses within the assessment process is not part of the scope of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 Summary of Literature Review

The purpose of this literature review is to support the research objective, which is to develop a taxonomy based assessment methodology for small and medium size manufacturers. The few publications which were found to deal with the problem of manufacturing assessments are dealt with in chapter three which focuses on the development of an assessment methodology. This literature review is organized based on the topics.

- Manufacturing Performance
  - Performance Measures
  - Drivers of Performance
- Competing Production Systems
- Manufacturing Taxonomies
- Assessments & Audits

2.1.1 Introduction to Literature

Obviously these topics are rather broad; exhaustive review of each topic is clearly beyond the scope of this research. However, works which were deemed to have the greatest relevancy in the achievement of the research objective (i.e., development of a taxonomy based assessment methodology) were prioritized and reviewed. Judgments regarding which publications were included in the review were made based on the following criteria.

- Relevancy to a holistic or enterprise-wide approach to manufacturing.
- Contribution to the development of an overall framework for describing manufacturing enterprises.
- Methodologies and techniques which may be applicable to the development of the assessment methodology.
- Contribution to the identification and organization of "best practices."

Of particular interest, little was found in the literature to address particular problems facing SMEs. One recent researcher provides the following commentary. "The paucity of attention given to the understanding of operations strategy of small and medium sized enterprises (SME), especially successful ones, is unfortunate as SMEs exert a strong influence on the economies of many countries."[23]

A brief synopsis of the reviewed literature follows. This is provided because of the difficulty in developing common threads among the widely varying publications on manufacturing performance, and improvement approaches. A more detailed review of the relevant publications follows.

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[23] Sum, C.C., Kow, L.S., Chen, C.S., "A Taxonomy of Operations Strategy of High Performing Small and Medium Size Enterprises in Singapore", 2004, International Journal of Operations and Production Management, 2004, Vol. 24, No. 3, pp. 322.

2.1.2 Brief Synopsis of Key Findings within the Literature

The synopsis highlights the most relevant findings in the literature with respect to the overall assessment approach.

The following references outlines the need for taxonomies within operations management research.

- Adam and Swamidass (1989) identified the need for the development of taxonomies and other classification schemes in order to improve operations management and strategy.[24] This challenge has to date only partly been addressed in the literature.
- Bolden et. al. (1997) The authors' review of taxonomies of practices referenced in the literature resulted in their conclusion that none describe the full coverage of manufacturing practices in use. This work clearly states that "there remains a need for the development of taxonomy which provides an overview of the domain of manufacturing practices and is not blinkered by its disciplinary origin."[25]

The following references the need for defining multiple dimensions of performance.

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24 E. E. Adam, P.M. Swamidass, Assessing Operations Management from a Strategic Perspective, Journal of Management, 1989, Vol. 15, No. 2, pp. 193.

25 Bolden R., Waterson, P., Warr, P., Clegg, C., Wall, T., "A New Taxonomy of Modern Manufacturing Practices, International Journal of Operations & Production Management, 1997, Vol. 17, No. 11, pp. 1114

- Sum et. al. (2004) indicate "Our analysis indicates that high performing enterprises compete effectively on multiple priorities simultaneously. … This finding that enterprises can compete effectively on multiple priorities." [26]

- Miller and Roth (1994) state "… in general, the manufacturing task is a multivariate, multidimensional construct that reflects the needs of widely different market environments and relative market positions."

- These approaches often lead organizations to take actions which result in diminished performance. Kaplan (1994) aptly summarizes this view, "General managers must be alert to the inadequacies of their present measurement system... managers must require both financial and non-financial indicators of manufacturing performance" [27]

- Ghalayini and Noble (1996) The consensus is that competitive advantage can be gained not just by being achieving the lowest cost, but is also reflective of other dimensions of performance (e.g., quality, flexibility, lead-time, and delivery reliability).[28]

- Ketokivi and Schroeder (2004) argue strongly in favor of treating manufacturing performance as a multidimensional response variable. Based upon an extensive literature

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[26] Sum, C.C., Kow, L.S., Chen, C.S., "A Taxonomy of Operations Strategy of High Performing Small and Medium Size Enterprises in Singapore", 2004, International Journal of Operations and Production Management, 2004, Vol. 24, No. 3, pp. 340

27 Kaplan, Robert S., "Yesterday's Accounting Undermines Production", Harvard Business Review, July-August, 1984, pg. 13

28 Alaa M. Ghalayini and James S. Noble, "The Changing Basis of Performance Measurement", International Journal of Operations and Production Management, Vol. 16, No. 8, 1996, pp. 63, University Press.

review, the following performance measures were used in this study: cost, quality, speed, deliver, volume flexibility, design flexibility.

- A manufacturing firm is an inherently highly integrated system, which lends itself more to a "cumulative" model rather than a "trade-off" model of capability development (reference Ferdows and De Meyer, 1991, Morita and Flynn, 1991, Kaithuria, 2000, Mapes et. al. 1997). However, this is not to imply that in reality there are not fundamental trade-offs involved within the manufacturing enterprise. In today's hyper-competitive market place, the manufacturing concern cannot be concerned about its performance within a narrow set of dimensions in isolation, all aspects of performance must be considered. The authors argue that their analysis indicates that high performing enterprises compete effectively on multiple priorities simultaneously.

The following provides critique of the current research approach.

- Davies and Kochhar (2002) provide several critiques of the practice-performance literature. They state that previous empirical research relies heavily upon subjectivity, and has therefore produced studies with "varying results which can be explained by successes and failures in their own methodologies."[29]
- Morita and Flynn (1997) conclude use of world class manufacturing principles is not a dichotomous variable, but rather a scaleable variable that varies based upon level of usage. Survey instruments from many previous researchers have not clearly

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[29] Davies, A.J. Kochhar, A.K., "Manufacturing Best Practice and Performance Studies: A Critique", International Journal of Operations and Production Management, Vol. 22, no. 3, 2002, pp. 302.

differentiated between those who have copied others and those that have truly built capabilities based upon the practices.

- Laugen et. al. (2005) conclude yet another weakness is that often times "best practices" are considered generic (i.e., universal best for all companies at all times). "The potential influence of factors like type of industry, company size, processes, and products is not considered, nor is the fact that practices, even the best ones, may become obsolete in the course of time."[30]

- Ketokivi and Schroeder (2004) Many of the previous studies collapsed multiple levels of performance into one a single overall measure of performance, which may be averaged across multiple dimensions. This method of treating multidimensionality of manufacturing response is not appropriate according to these authors.

The following illustrates the importance of extended enterprise relationships

- Lowe (1997) "Furthermore, the fact that high performing plants benefited from better customer/supplier relationships highlights the limitations of studies which focus exclusively on plant level practices and suggests that the wider context in which plants operate have a crucial bearing on plant performance ." [31]

The following papers discuss the need for greater understanding of cause and effect relationships within the manufacturing enterprise.

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[30] Laugen, B.T., Acur, N., Boer, H., Frick, J., "Best Manufacturing Practices: What do the best performing companies do?", International Journal of Operations and Production Management, Vol. 25, No.2, 2005, pp. 131-150.

[31] Ibid, pg. 185

- Another concern identified by Davies and Kochhar (2002) is the linkages found in the literature are only general in nature with "little cause and effect analysis of the impact of these practices on performance."[32]

- Another issue, identified by Bolden (1997), is the vague and inconsistent use of terminology from study to study. This is a barrier when attempting to build a body of knowledge which draws upon conclusions from a variety of studies

The following references highlight the need for consistent definition of best practices

- Morita and Flynn (1997) comment that frequently empirical studies have failed to differentiate between immature uses of a practice and those that have implemented the practice extensively.

- Laugen et. al. (2005) conclude yet another weakness is that often times "best practices" are considered generic (i.e., universal best for all companies at all times). "The potential influence of factors like type of industry, company size, processes, and products is not considered, nor is the fact that practices, even the best ones, may become obsolete in the course of time."[33]

- Laugen et. al. (2005) The term action program was used rather than practices, because the program is defined by a bundle of practices. For example, Pull Manufacturing is defined as an action program which includes the bundling of specific practices like

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[32] Ibid, pg. 290

33 Laugen, B.T., Acur, N., Boer, H., Frick, J., "Best Manufacturing Practices: What do the best performing companies do?", International Journal of Operations and Production Management, Vol. 25, No.2, 2005, pp. 131-150.

kanban and SMED. The linkage developed between usage of world class practices and performance is a clear indication that a firm can compete through manufacturing." [34]

- Useful guidelines and definitions on the subject of best practices are provided by Davies and Kochhar (2002). They define best practices as "those that have aided the lower performing companies to improve to medium performance, medium performers to high performers, and higher performers to continue to be successful and achieve further benefits."[35]

The following suggests multiple paths to improvements are possible.

- Kathuria's (2000) work suggests "different manufacturers use different bases to compete in the same industry."[36] This implies that different firms may pursue totally different strategies and yet be equally effective.

The following papers reference the need for best practices to be clustered, context specific, and driven by strategy.

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34 Morita, Michiya, Flynn, James, "The Linkage Among Management Systems, Practices and Behavior in Successful Manufacturing Strategy, International Journal of Operations & Production Management, Vol. 17, No. 10, 1997, pg. 979

35 Davies, A. J., Kochhar, A. K., Manufacturing Best Practice and Performance Studies: A Critique, International Journal of Operations & Production Management, Vol. 22, No. 3, 2002, pg. 302

[36] Kathuria, R. "Competitive Priorities and Managerial Performance: a taxonomy of small manufacturers", Journal of Operations Management, 2000, Vol. 18, pg.638.

[36] Bolden R., Waterson, P., Warr, P., Clegg, C., Wall, T., "A New Taxonomy of Modern Manufacturing Practices, International Journal of Operations & Production Management, 1997, Vol. 17, No. 11, pp. 1114.

- Also Davies and Kochhar (2202) concluded after an extensive literature review that "best practices are context specific."[37] Contextual factors include maturity of the company, infrastructure of reporting, and type of industry. Also the authors conclude that practices must be evaluated "by a more holistic approach that takes account of influences on other areas of performance rather than just the desired area to be improved." [38]

- Morita and Flynn (1997) found that merely adopting certain practices appears to have limited benefits. Extensive use of a broader set of these practices appears to relate to a higher level of performance.[39] Also Morita and Flynn (1997) study *showed that a high degree of correlation existed between "strategic focus" cluster of practices and all seven aspects of performance.* This indicates that manufacturing strategy is important to competitive success for these firms.

- Morita and Flynn (1997) Clearly, there is a high degree of correlation between practices. The effect of a particular practice is contingent upon the presence of other practices. "Each cluster is a set of contingent, or linked, practices which should be selected together for maximum effectiveness." [40]

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[37] Ibid.

[38] Ibid., pg. 303

[39] Morita, Michiya, Flynn, James, "The Linkage Among Management Systems, Practices and Behavior in Successful Manufacturing Strategy, International Journal of Operations & Production Management, Vol. 17, No. 10, 1997, pg. 979

[40] Morita, Michiya, Flynn, James, "The Linkage Among Management Systems, Practices and Behavior in Successful Manufacturing Strategy, International Journal of Operations & Production Management, Vol. 17, No. 10, 1997, pg. 977

- Sakakibara et. al. (1997) concluded the following. "In fact, all infrastructure practices were highly correlated with each other…. This implies that a plant that shows strength in quality management is very likely to have good practices in other areas."[41]

- Morita and Flynn (1997) concluded the addition of interaction variables in the model resulted in the authors concluding "while quality management and JIT function effectively in isolation, their combination yields synergies which lead to further performance improvements."[42]

- Ketokivi and Schroeder (2004) provide insight into the published research by arguing for the inclusion of strategic contingency variables. Fundamental to their premise is that the effect of particular manufacturing practices on performance is contingent upon the strategic importance that the firm places upon the practice.

- The Ketokivi and Schroeder (2004) study concludes " … manufacturing operations and practices are indeed strategic, that there are few best practices in the sense that they contribute to the competitive manufacturing performance in multiple dimensions." … "Incorporating strategic priorities into the analysis has provided us with a better understanding of the practice-performance relationships. The evidence shows that some practices are better suited to some strategies than to others."[43]

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[41] Sakakibara, Flynn, Schroeder, Morris "The Impact of JIT Manufacturing and Its Infrastructure on Manufacturing Performance." Management Science, 1997, 43 (9): pp. 1256.

[42] Morita, Michiya, Flynn, James, "The Linkage Among Management Systems, Practices and Behavior in Successful Manufacturing Strategy, International Journal of Operations & Production Management, Vol. 17, No. 10, 1997, pg. 977

[43] Ketokivi, M., Schroeder, R., "Manufacturing Practices, Strategic Fit and Perfromance: A Routine-Based View", International Journal of Operations and Production Management, Vol. 24, No. 2, 2004, pp. 182-185.

- Das and Jayaram (2003) conclude with the following. "It is apparent that the influence of AMT on manufacturing performance depended on the extent of leanness exhibited by the plant. Complimenting this lean structuring or lean initiatives were work practices. Considering these two effects together, the findings suggest that plants which combine lean initiatives and work organization structures exhibit a higher variance in manufacturing performance that can be traced to AMT deployment."[44]

The following conclusions appear to be relevant with respect to the development of assessment methodology

- Ford et. al. concludes "As a consequence of our findings, we are prone to consider the 'self' in self assessment a bit of a misnomer ... organizations often appear to rely substantially on outsiders to facilitate self-assessment."[45]

- Of particular interest are the comments of Ritchie and Dale (2000), there is an apparent "lack of assistance provided in directing an organization toward a specific approach. Perhaps this is because there is more revenue to be gained by management consultancies if they only provide general comments on an approach… It could also be seen as an oversight of the quality management researchers in not giving this the attention that it deserves."[46]

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[44] A . DAS, J. Jayaram, "Relative Importance of Contingency Variables for Advanced Manufacturing Technology", International Journal of Production Research, 2003, Vol. 41, No. 18, pg. 4447

[45] Ford, M. W., Evans, J. R., Matthews, C. H., "Linking Self Assessment to the External Environment: An Exploratory Study", International Journal of Operations & Production Management, Vol. 24, No. 11, 2004, pg. 1184.

[46] Ritchie, L., Dale, B.G., "An Analysis of Self-Assessment practices Using the Business Excellence Model", Proceedings of the Institution of Mechanical Engineers, 2000, pg. 600.

2.2 Manufacturing Performance

Several major themes have surfaced in the manufacturing performance literature during the last 15 years. These themes include performance measures, manufacturing strategy, and best practices. Numerous empirical studies have been conducted which attempt to characterize what appears at times to be a somewhat elusive relationship between practice and performance. The studies published in this arena are quite varied and have produced a wide spectrum of results. However, there is a general recognition in the literature that firms should view manufacturing as a strategic resource.

2.2.1 Performance Measures

Since the purpose of the assessment is to provide a methodology which results in enhanced manufacturing performance, the issue of how to measure performance in a manufacturing setting is relevant. Particularly insightful is the following quote from the Foundation of Manufacturing Committee of the National Academy of Engineering found in the work published by Ghalayni and Noble (1996). "World class manufacturers recognize the importance of metrics in helping to define the goals and performance expectations for the organization."[47]

There is general agreement in the literature that manufacturing performance should not be viewed strictly in financial sense, but is inherently multidimensional (e.g., cost, quality, delivery, flexibility). Ghalayini and Noble (1996), Kaplan (1984), Goldratt (1984), among others suggest

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47 Ghalayini A.M., Noble, J. S., The Changing Basis of Performance Measurement", International Journal of Operations and Production Management, Vol. 16, No. 8, 1996, pp. 63.

that traditional performance measures driven from standard cost systems are at best severely limited. These approaches often lead organizations to take actions which result in diminished performance. Kaplan (1994) aptly summarizes this view below. "General managers must be alert to the inadequacies of their present measurement system... managers must require both financial and non-financial indicators of manufacturing performance" [48]

Similar conclusions were reached by White (1996), who concurs with the idea that performance is multi-dimensional. However, he also mentions that a consensus has not been reached concerning the best way to measure these dimensions and which measures should be used in what circumstances. Also he provides an excellent summary of strategy related performance measures recommended in the literature. White's summary of his consolidated list of 125 different measures is provided in the following Table. (reference Table 2.1). This list was refined from several hundred considered in his research.

The premise of Ghalayni et. al. (1996) work is that the basis of performance measurement has undergone a fundamental change. For the first 100 years the emphasis was placed strictly on financial measures like profit, productivity, and ROI. However, this basis changed during the late 1980's, when manufacturing competition reached new heights. It is now commonly recognized that competitive advantage can be gained not just by achieving the lowest cost, but it is also reflective of other dimensions of performance (e.g., quality, flexibility, lead-time, and delivery reliability).[49] This paper presents limitations of traditional measures, characteristics of recently

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48 Kaplan, Robert S., "Yesterday's Accounting Undermines Production", Harvard Business Review, July-August, 1984, pg. 13

[49] Alaa M. Ghalayini and James S. Noble, "The Changing Basis of Performance Measurement", International Journal of Operations and Production Management, Vol. 16, No. 8, 1996, pp. 63, University Press.

developed performance measures, integrated performance measurement systems (e.g., Balanced Scorecard), and recommendations for future systems.

Ghalayni and Noble (1996) state that traditional measures have been based upon management accounting systems. According to their literature review, the consensus is that productivity is the key financially driven performance measure. Numerous definitions and models of productivity have been advocated. For example, total factory productivity has been defined as "the ratio of total output to the sum of associated labor and capital factors." [50] This work identifies the numerous limitations to this type of traditional measure, based upon their literature review. The most important of these limitations are summarized in following Table 2.1. These critiques are perhaps best summarized by a direct quote from Kaplan used in this article. Kaplan states "Traditional summary measures of local performance – purchase price variances, direct labor and machine efficiencies, ratios of indirect to direct labor, absorption, and volume variances – are harmful and should be eliminated, since they conflict with attempts to improve quality, reduce inventories, and increase flexibility."[51]

Non-traditional performance measures have recently emerged in published work. These measures are driven from the firm's strategy and are primarily operational (i.e., non-financial). Characteristics of these new measures include such things as support for daily decision making, facilitation of ease of understanding by employees, encouragement of improvements rather than monitoring, supportive of change as required by the business.[52] Ghalayni and Noble (1996) state that much of the recent literature contends that time is the key emerging metric. "The importance

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[50] Ibid, pg. 64

[51] Ibid, pg. 67

[52] Ibid, pg. 67

of time can be realized by the following argument: measuring, controlling, and compressing time will increase quality, reduce costs, improve responsiveness to customer orders, enhance delivery, increase productivity, reduce risks since reliance on forecast is reduced, increase market share, and increase profits."[53] Furthermore, Krupka (1992) as summarized by Ghalayni and Noble (1996) argues that variability in time is an important performance measure. Reducing the variability of a process through elimination of non-value add occurrences (e.g., downtime, scrap, re-work, reducing batch sizes, etc.) will drive improvements in quality and costs.

Table 2.1

Limitations of Traditional Financial Based Performance Measures

Reference: Ghalayni et. al. 1996	
Limitation	*Explanation*
Accounting Systems	This is the *most significant* of all the limitations. Developed during a period where labor was the major cost driver and overhead was minor. Today, labor is rarely over 12% of total cost and overhead accounts for over half of the product cost. "Since in this case overhead is allocated based upon the minor cost element of direct labor this allocation approach is invalid."
Lagging Metrics	Financial reports are produced as a result of past decisions, often on a monthly basis, which does not stimulate timely action.
Corporate Strategy	Since the focus is on measures that drive cost, other aspects of strategy are ignored.
Relevance to Practice	Most operational improvements are difficult to quantify in terms of dollars (e.g., LT).
Customer Requirements	Emphasis on meeting customer quality, delivery, and lead-time expectations requires a greater level of autonomy at lower levels within the organization. Strictly, financial measures "do not reflect a more autonomous management approach."
Productivity	"Moreover, focusing excessively on the efficiency of factory workers and departments detracts attention from improving the production system itself."
Cost	"Low cost is only one and no longer the most important factor for competing in most markets. Skinner argues that to be competitive you should concentrate on quality, rapid delivery, short lead-times, customer service, …."

[53] Ibid, pg. 68

The consensus is that competitive advantage can be gained not just by achieving the lowest cost, but also by considering other dimensions of performance (e.g., quality, flexibility, lead-time, and delivery reliability).[54] The relative importance of these other aspects of performance is dependent on a firm's manufacturing strategy. There is an increasing recognition among published work that performance measures must be strategic, timely, relevant, and balanced.

Skinner (1969), Wheelwright (1978), and others argue that performance measures should be closely linked to strategy. Hayes and Wheelwright in their seminal 1978 work claim that the "product-process matrix" can be helpful to firms in their quest to develop an overall manufacturing strategy. The premise is that the manufacturing system must evolve over time in concert with the evolution of the product along its life cycle. Other works were found to deal with frameworks usable by firms when developing a manufacturing strategy (e.g., Skinner, 1969, ….). Morita and Flynn (1997) claim that manufacturing strategy includes the type of product to be produced, where and to whom will it be sold. Product features (e.g., quality, reliability, cost, and delivery) become the basis for assessing manufacturing performance. These performance measures then drive the firm's continuous improvement efforts.

Adam et. al. (1989) provide a useful review of a 20 year span of publications in the field of manufacturing strategy, which is inherently linked to measures of performance. They argue that a major theme in the literature is the importance of formulating a manufacturing strategy.

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[54] Alaa M. Ghalayini and James S. Noble, "The Changing Basis of Performance Measurement", International Journal of Operations and Production Management, Vol. 16, No. 8, 1996, pp. 63, University Press.

According to these authors, the core content of the strategy involves cost, quality, flexibility, and technology. This work presents concepts or themes in which there is broad consensus in the literature as “common themes.” The “missing themes” provide insight and direction to guide future research efforts. Clearly most of the missing themes have shown up in the literature since this work was first published in 1989. However, of particular interest to this research is the fact that Adam et. al. identified the need for the development of taxonomies and other classification schemes in order to improve operations management and strategy.[55] This literature review sixteen years later indicates that the development and use of robust classification schemes remain, largely missing in the operations management body of work.

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[55] E. E. Adam, P.M. Swamidass, Assessing Operations Management from a Strategic Perspective, Journal of Management, 1989, Vol. 15, No. 2, pp. 193.

Table 2.2

Thematic Review of Manufacturing Strategy Literature

Reference: Adam et. al. 1989
Common Theme #1: The process of formulating & implementing manufacturing strategy is important for guiding manufacturing. Common Theme #2: The core content of manufacturing strategy includes cost, quality, flexibility, and technology.
Missing Theme #1: Operations strategy research needs distinct research streams investigating strategy content and strategy process. Missing Theme #2: Strategic planning is an important strategy process tool for operations management. Missing Theme #3: The real test of operations strategy is its effect on operating and overall performance. Missing Theme #4: Operations strategy theory development should use empirical research as building blocks *Missing Theme #5: The development of taxonomies and classification schemes would improve operations management and strategy.* Missing Theme #6: Operations management needs to reflect the international context of business. Missing Theme #7: Major Themes in the operations management literature such as JIT, productivity, and quality are not integrated into manufacturing and operations strategy.

Table 2.3

White's Measures of Competitive Capability

Cost	*Quality*	*Flexibility*	*Delivery Reliability*	*Speed*
Relative to competitors (actual, perceived)	Relative to Competitor	Flexibility Perceived, Volume Flexibility	Relative Reliability	Lead-Time
Mfging Cost	Product Reliability	Flexibility Relative to competitors	Relative to Competitors	Cycle Time
Capital Productivity	Product Durability	Quality Impacted by Mix	% on-time Delivery	Customer Recognition of Need to Delivery
Labor Productivity	% customer satisfied	Cost impacted by Mix	Due Date Performance	Order Processing Time
Machine Productivity	Customer Satisfaction	Delivery Impacted by Mix	% increase in meet delivery promises	Response Time
Total Factor Productivity	Reputation, Expected life	# of Part Types made simultaneously	% of orders with incorrect quantities.	% on-time for "rush"
Product Cost as a Function of LT	# of Complaints	Production CT, Make/Total Time	Schedule performance	Paperwork throughput
Direct Labor	Service Call Rate, Retention Rate	Set-Up Time, Tools, Fixtures	Average Delay	Material throughput
Indirect Labor	Defect Level	% increase in setups/day	% reduction in LT by line	Value Add as % of total time
% improvement in labor	Value of returns	Adapt to Volume Change	% reduction in purchasing LT	Distance Traveled
Relative labor cost	% reduction in warranty claims	Smallest Economical Volume	% reduction in service of warranty claim	Decision CT
Labor Efficiency	% field failure, MTBF	Lot Size, Multiple tasks Efficiently		% first competitor to market
% setup time improvement per line	% Uptime, % reduction in DT	Job Classification, % cross-trained		New Product Introduction vs Competitor
% reduction in employee turnover	Pass Rate, % conform to targets	% more than one job per month		Development time
Materials	Assy Line Defect Rate	% increase in # of direct labor skills		Breakeven Time
Inventory, Scrap	% with no repair	% programmable equip.		Time: idea to market
% Inventory Turnover Increase	% reduction in time detect-correct	% multi-purpose equipment		Average time between Innovations
Repair, Cost of Quality	% scrap, % scrap reduction	% decrease in # of bottlenecks		# of changes in projects
Design Cost	Repair people/ direct person	% of slack time (protective capacity)		Engineering Time
R&D Expenditure	% inspections eliminated	% products using Pull, WIP		
Distribution Cost	Cost of Quality, Vendor Quality	Disruptions caused by DT		
% reduction in transactions/product	% Supplier Reduction	Vendor LT. % increase in vendor output		

Fry (1995) studied eight plants from five different Japanese manufacturing firms. The objective of this study was to determine what factors were important to success, identify the performance criteria at various levels within the organization, and to determine what type of measures were used depending upon the level within the organization. Fry classifies measurements into two categories: financial and physical.

Fry concluded that contrary to earlier studies top level Japanese managers were evaluated heavily by financial measures. However, they did conclude that these senior managers tended to not push down the responsibility of financial measures to lower levels in the organization. Measures that lower and mid-level managers were responsible for tended to be physical (e.g., number of defects, absenteeism, safety, …). Also, financial measures tend to be driven by actual costs as opposed to standardized costs, which are common in traditional cost accounting systems.

Some debate exists in the literature as to whether firms should view aspects of performance (e.g., cost, quality, speed, delivery, …) as "trade-offs" or as "cumulative". The trade-off position (Skinner 1969) states that successful firms must develop excellence on certain performance attributes, to the exclusion of others. For example, a firm may decide to focus on low cost with high delivery reliability at the expense of quality and flexibility. The "cumulative" or "sand cone" view[56] states that that capability is best developed cumulatively, due to the interrelationship between dimensions of performance. According to this view, capability is developed in a manner similar to the building of a multi-layered sand cone. The first layer of the sand cone is a foundation of quality improvements. To increase the size of the sand cone, additional sand is poured which expands the quality foundation and targets the dependability of

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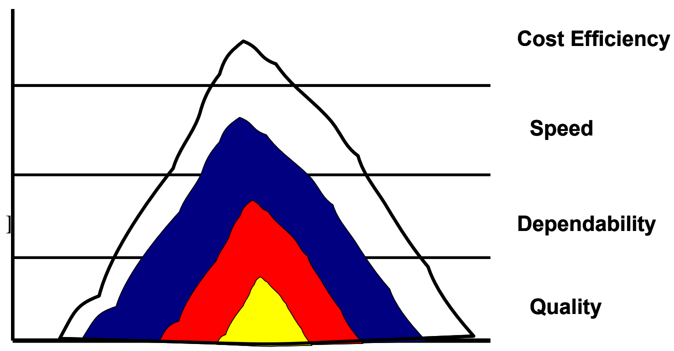
[56] Ferdows, Karsa, De Meyer, Arnoud, "Lasting Improvements in Manufacturing Performance: In Search of a New Theory", Journal of Operations Management, Vol. 9, No. 2, April 1990, pg. 175.

the production system. Enhancements in speed are next added while efforts continue to improve quality and dependability. Finally, as efforts continue to focus on the other layers only then can a substantive cost improvement program be developed. Therefore, the increasing levels of performance are achieved cumulatively, making it very difficult for competitors to duplicate.



Reference: Ferdows and De Meyer, 1990

Figure 2.1 "Sand Cone" Model of Manufacturing Capability Development

According to Mapes et. al. (1997) some researchers have advocated a modification of the trade-off model. This position states that the nature of the trade-offs are changing, while some trade-offs remain unchanged. According to this position, the term trade-off should be avoided in favor of performance relationships. Also, Mapes focused on quantifying the inter-relationships between measures of performance; paired correlation coefficients were estimated on manufacturing cost, quality consistency, delivery reliability, innovation rate, and product variety. They conclude "rankings on most measures of operating performance show significant positive correlations with each other. Not only is there an absence of trade-offs, good performance on one measure seems to lead to good performance on other measures." [57]

2.2.2 Drivers of Performance

Numerous studies have been published attempting to develop relationships between performance and key predictor variables. These studies typically involve the development of a survey instrument sent across a large number of firms in order to empirically define relationships. Miller and Roth (1994) state the following. "… These findings suggest that in general, the manufacturing task is a multivariate, multidimensional construct that reflects the needs of widely different market environments and relative market positions." [58] Numerous studies were found in the literature which attempt to link a variety of factors (e.g., plant size, location, level of automation, practices, …) with plant performance.

Summarizing these studies is somewhat difficult, due to wide ranging approaches and conclusions from these studies. Comments were found in the literature, which indicated the difficulty in summarizing the state of knowledge in this field.[59]

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57 Mapes, John, New, Colin, Szwejczewski, Marek, "Performance Trade-offs in Manufacturing Plants", International Journal of Operations & Production Management, Vol. 17, No. 10, 1997, pg. 1031

58 Miller, Jeffrey G., Roth, Aleda V., "A Taxonomy of Manufacturing Strategies", Management Science, Vol. 40, No. 3, March 1994, pp. 294.

59 Davies, A.J. Kochhar, A.K., "Manufacturing Best Practice and Performance Studies: A Critique", International Journal of Operations and Production Management, Vol. 22, no. 3, 2002, pp. 302.

2.2.2.1 Overview of Publications

Davies and Kochhar (2002) provide several critiques of the practice-performance literature. They state that previous empirical research relies heavily upon subjectivity, and has therefore produced studies with "varying results which can be explained by successes and failures in their own methodologies."[60] To re-enforce this finding, the publications found during this review have almost exclusively relied upon the respondent's subjective evaluation of performance. Another concern identified by Davies and Kochhar is the linkages found in the literature are only general in nature with "little cause and effect analysis of the impact of these practices on performance."[61] Another issue, identified by Bolden (1997), is the vague and inconsistent use of terminology from study to study. This is a barrier when attempting to build a body of knowledge which draws upon conclusions from a variety of studies. Morita and Flynn (1997) comment that frequently empirical studies have failed to differentiate between immature uses of a practice and those that have implemented the practice extensively. Laugen et. al. (2005) conclude yet another weakness is that often times "best practices" are considered generic (i.e., universal best for all companies at all times). "The potential influence of factors like type of industry, company size, processes, and products is not considered, nor is the fact that practices, even the best ones, may become obsolete in the course of time."[62]

Despite the aforementioned concerns, some general and perhaps tenuous, conclusions can be drawn from the published record.

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60 Davies, A.J. Kochhar, A.K., "Manufacturing Best Practice and Performance Studies: A Critique", International Journal of Operations and Production Management, Vol. 22, no. 3, 2002, pp. 302.

61 Ibid, pg. 290

62 Laugen, B.T., Acur, N., Boer, H., Frick, J., "Best Manufacturing Practices: What do the best performing companies do?", International Journal of Operations and Production Management", Vol. 25, No.2, 2005, pp. 131-150.

- General types of practices are commonly considered "best practices." The degree of impact might be different depending upon the context, but there is general agreement regarding a common set of best practices that have been evaluated in a variety of studies.
    - Individual practices cannot be evaluated in isolation. The best evidence suggests that certain practices tend to be clustered together within high performing firms. The implication is that the success of a practice may be "contingent" upon the presence of other practices as well as other mitigating variables.
    - Best practice is defined as those practices that enable firms to go from lower to higher performance or from higher performance to even higher levels of performance. Also they may not be the same for every company and are likely to differ over time.
- A manufacturing firm is an inherently highly integrated system, which lends itself more to the "cumulative" model rather than the "trade-off" model of capability development (reference Ferdows and De Meyer, 1991, Morita and Flynn, 1991, Kaithuria, 2000, Mapes et. al. 1997). However, this is not to imply that in reality there are not fundamental trade-offs involved within the manufacturing enterprise.
    - In today's hyper-competitive market place, the manufacturing concern cannot be concerned about its performance within a narrow set of dimensions in isolation. All aspects of performance must be considered.
    - The authors argue that their analysis indicates that high performing enterprises compete effectively on multiple priorities simultaneously. This finding is contrary to the "trade-off notions found in Skinner (1969), Banks and Wheelwright (1979), and Miller (1983). These publications advocate that firms ought to focus on a

relatively narrow set of task/capabilities. Sum et al.'s work re-enforces the results of Kathuria (2000) and Roth and Miller (1990, 1992) that suggest that enterprises could offer and be competent in multiple priorities.[63]

2.2.2.2 Review of Specific Publications

Lowe, et. al. (1997) examine the linkage between lean production practices and performance. Performance is measured in terms of plant level productivity and quality and not based upon financial measures. Lean proponents state that lean practices are a "universal set of best practices" which yield performance benefits at the establishment level, regardless of context and environment". [64] This hypothesis was tested by surveying 71 tier one automotive supplier plants. These plants represent a range of products (i.e., seat plants, brake caliper plants, and exhaust plants) from plants located in North America, Europe and Japan. This work concluded that high performing plants exhibit "process control and discipline." In addition, the study indicated that high performing plants tend to exist within high performing supply chains. The supply chain effect means that suppliers tend to provide on-time deliveries and high quality products, when customers provide them stable production requirements. Interesting insight was mentioned in the following quote. "Furthermore, the fact that high performing plants benefited from better customer/supplier relationships highlights the limitations of studies which focus

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[63] Sum, Chee-Choung, Kow, Lynn, and Chen, Cheng-Shen, "a Taxonomy of Operations Strategies of High Performing Small and Medium Enterprises in Singapore", International Journal of Operations & Production Management", Vol. 24, No. 3, 2004, pg. 340

[64] James Lowe, Rick Delbridge and Nick Oliver. High-Performance Manufacturing: Evidence from the Automotive Components Industry. Organization Studies; 1997, 183-198.

exclusively on plant level practices and suggests that the wider context in which plants operate have a crucial bearing on plant performance ." [65]

Useful guidelines and definitions on the subject of best practices are provided by Davies and Kochhar (2002). They define best practices as "those that have aided the lower performing companies to improve to medium performance, medium performers to high performers, and higher performers to continue to be successful and achieve further benefits."[66] Also, their conclusion after an extensive literature review is that "best practices are context specific."[67] Contextual factors include maturity of the company, infrastructure of reporting, and type of industry. Also, the authors conclude that practices must be evaluated "by a more holistic approach that takes account of influences on other areas of performance rather than just the desired area to be improved." [68]

Laugen et. al. (2005) work focuses on the research question "Which practices are used by the best performing organizations?"[69] Their critique of previous work is that they often assume a positive impact of a particular practice (e.g., JIT) and that certain practices are "best for all companies always." Their approach was to first separate high and low performing firms based upon their reported performance in terms of quality, flexibility, speed, and cost. The survey asked questions regarding the level of usage of action programs. The term action program was used

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[65] Ibid, pg. 185

[66] Davies, A. J., Kochhar, A. K., Manufacturing Best Practice and Performance Studies: A Critique, International Journal of Operations & Production Management, Vol. 22, No. 3, 2002, pg. 302

[67] Ibid.

[68] Ibid., pg. 303

[69] Laugen, B. T., Acur, Nuran, Boer, Harry, Frick, Jan, "Best Manufacturing Practices: What do the best performing companies do?", International Journal of Operations and Production Management, Vol. 25, No. 2, 2005, pg. 132

rather than practices, because the program is defined by a bundle of practices. For example, Pull Manufacturing is defined as an action program which includes the bundling of specific practices like kanban and SMED. This study attempted to evaluate whether specific practices (i.e., action programs) explained the differences in performance between high and low performing firms.

The linkage developed between usage of world class practices and performance is a clear indication that a firm can compete through manufacturing. However, merely adopting certain practices appears to have limited benefits. Extensive use of a broader set of these practices appears to relate to a higher level of performance. "In turn, this implies the sand cone model (Ferdows and De Meyer) may be a valid way of conceiving the evolution of factory competitive capabilities and performance." [70]

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[70] Morita, Michiya, Flynn, James, "The Linkage Among Management Systems, Practices and Behavior in Successful Manufacturing Strategy, International Journal of Operations & Production Management, Vol. 17, No. 10, 1997, pg. 979

Table 2.4

Laugen et. al.'s Identification of Best Practices

Reference: Laugen et. al. (2005)		
Action Program	Best Practice	Notes
Process Focus	Yes	Shows synergetic effects on virtually all dimensions of performance.
Pull Production	Yes	
Equipment Productivity	Yes	
Environmental Compatibility	Yes	
E-Business	Possibly	Least frequently adopted, negatively related to flexibility. New concept
Supplier Strategy	Possibly	Impact is limited, some evidence on positive effect on cost.
Outsourcing	Possibly	
New Product Development	Possibly	Have mixed effects on operations performance – positive effects on flexibility and cost, no positive impact on other measures of performance.
Process Equipment	No	Appears to produce no significant effects on performance.
Manufacturing Capacity	No	
Process Automation	No	
Workplace Development	No	
Quality Management	No Longer	Due to wide spread acceptance, no longer a difference maker relative to competition. Supporting practice that should be regarded as routine.
IT & Communications	No Longer	

Flynn, Schroeder, et. al. (1997) describe the World Class Manufacturing (WCM) Project. This work builds from the earlier work of Hayes and Wheelwright (1985) and Schonberger (1986), by developing a survey instrument and results database. Hayes and Wheelwright (1985) coined the term "World Class Manufacturing" (WCM) to reflect the attainment of competitive advantage through enhanced manufacturing capability. They focus on key practices like workforce development, technically competent management team, strong emphasis on quality, and investments in appropriate technologies. Schonberger (1986) added to the body describing WCM by focusing on continuous improvement, supplier relationships, JIT practices (e.g., SMED, Kanban,, TPM, Poke-a-yoke, etc.). The paper provided the following concluding remarks. "The effects of quality management and JIT practices were shown most salient through their interactions. Quality management practices interacted with common infrastructure practices and JIT practices to reduce cycle-time. In addition, quality management practices facilitate cycle-time reductions through reducing the time required for re-work of defective items and production of non-value added scrap. … The plants with the best quality performance are given an added boost through JIT's ability to pinpoint problems for subsequent solution using quality management practices." [71]

Morita and Flynn (1997) surveyed Japanese manufacturing firms; evaluations were conducted on unit cost, conformance quality, delivery performance, production cycle-time, product capability, and customer support. They identify 11 key management characteristics. The firms labeled "world class" show significantly greater impact on five of the seven aspects of performance than the "emerging world class firms." Also "world class" firms show a significant improvement on all seven measures of performance when compared to the random sampling of firms. This bolsters the argument that the practices and characteristics associated with world class manufacturing lead to enhanced firm performance. Also Morita and Flynn's study showed that a high degree of correlation existed between "strategic focus" cluster of practices and all seven

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[71] Barbara B. Flynn, Roger G. Schroeder, E. James Flynn, Sadao Sakakibara and Kimberly A. Bates. "World-Class Manufacturing Project: Overview and Selected Results". International Journal of Operations and Production Management; 1997, Volume 17, No. 7, pp. 683.

aspects of performance. This indicates that manufacturing strategy is important to competitive success for these firms.

Morita and Flynn conclude use of world class manufacturing principles is not a dichotomous variable, but rather a scalable variable that varies based upon level of usage. Survey instruments from many previous researchers have not clearly differentiated between those who have copied others and those that have truly built capabilities based upon the practices. Clearly, there is a high degree of correlation between practices. The effect of a particular practice is contingent upon the presence of other practices. "Each cluster is a set of contingent, or linked, practices which should be selected together for maximum effectiveness." [72]

Flynn, Schroeder, et. al. (1997) describe the World Class Manufacturing (WCM) Project. This work builds on earlier work by Hayes and Wheelwright (1985) and Schonberger (1986), by developing a survey instrument and results database. A variety of empirical relationships were evaluated using this data. Data was collected across various types of industries (i.e., electronic, transportation, and machinery). The following studies were conducted.

- S1: patterns of manufacturing process innovation
- S2: impact on quality management practices on performance
- S3: interrelationships between quality management and JIT.

In the first study (S1) one of the findings was that manufacturing organizations could be grouped into four clusters based upon their adoption of innovations. The second study (S2) seeks to relate specific quality management practices (i.e., product design process, process flow management, and statistical control and feedback) to various dimensions of quality performance

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72 Morita, Michiya, Flynn, James, "The Linkage Among Management Systems, Practices and Behavior in Successful Manufacturing Strategy, International Journal of Operations & Production Management, Vol. 17, No. 10, 1997, pg. 977

(i.e., perceived quality market outcomes, percentage pass @ final inspection). The relationship between quality performance and competitive advantages (i.e., low cost, fast delivery, volume flexibility, inventory turnover, and cycle time) was also tested. In addition, quality management infrastructure practices (i.e., customer relationship, supplier relationship, workforce management, work attitudes, and top management support) were evaluated from the perspective of an indirect effect on quality performance through QM practices. This work concluded the following

- Infrastructure variables alone were sufficient to predict JIT performance. The addition of unique JIT variables to the infrastructure variables led to further improvements in JIT performance. The addition of TQM variables did not significantly affect JIT performance.
- Infrastructure variables alone explained approximately 50% of quality performance. The addition of unique quality practices and unique JIT practices did not significantly increase quality performance.
- The addition of interaction variables in the model resulted in the authors concluding "while quality management and JIT function effectively in isolation, their combination yields synergies which lead to further performance improvements."[73]

The paper provided the following concluding remarks. "The effects of quality management and JIT practices were shown most salient through their interactions. Quality management practices interacted with common infrastructure practices and JIT practices to reduce cycle-time. In addition, quality management practices facilitate cycle-time reductions through reducing the time required for re-work of defective items and production of non-value

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[73] Morita, Michiya, Flynn, James, "The Linkage Among Management Systems, Practices and Behavior in Successful Manufacturing Strategy, International Journal of Operations & Production Management, Vol. 17, No. 10, 1997, pg. 977

added scrap. The plants with the best quality performance are given an added boost through JIT's ability to pinpoint problems for subsequent solution using quality management practices." [74]

Sakakibara, Flynn, et. al. (1997) claimed that the success of JIT depends upon the maturity level of the overall organization. Further, this study indicates that JIT practices have no direct effect on performance, but work through the manufacturing infrastructure by providing targets and a discipline. Perhaps this finding explains why many manufacturers fail in their JIT implementation by focusing too much on specific practices, to the neglect of developing their infrastructure. In this study infrastructure refers to the management of strategy, quality, and the workforce management. In addition, they found a strong degree of interconnectedness between various manufacturing practices.

Table 2.5

JIT Manufacturing, Infrastructure, and Performance

(reference: Sakakibara, Flynn, et. al. 1997)			
JIT Practices	*Infrastructure for JIT*	*Mfging Performance*	*Competitive Advantage*
Set-up time reduction	Product Design	Inventory turnover	Overall Advantage
Scheduling flexibility	Workforce Practices	On-time Delivery	Flexibility
Maintenance	Organizational Characteristics	Lead-Time	Delivery
Equipment layout	Quality Management	Cycle-time	Quality
Kanban, Supplier Relations	Manufacturing Strategy		Cost

[74] Barbara B. Flynn, Roger G. Schroeder, E. James Flynn, Sadao Sakakibara and Kimberly A. Bates. "World-Class Manufacturing Project: Overview and Selected Results". International Journal of Operations and Production Management; 1997, Volume 17, No. 7, pp. 683.

Particular discussion is focused on the conclusion from H4, which indicated that manufacturing performance can be explained by infrastructure practices alone without consideration of JIT practices. "Before drawing the conclusion that stressing infrastructure is sufficient to compete, however the interconnected relationships among different manufacturing practices should also be investigated…. In fact, all infrastructure practices were highly correlated with each other…. This implies that a plant that shows strength in quality management is very likely to have good practices in other areas."[75]

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[75] Sakakibara, Flynn, Schroeder, Morris "The Impact of JIT Manufacturing and Its Infrastructure on Manufacturing Performance." Management Science, 1997, 43 (9): pp. 1256.

Table 2.6

Conclusions: JIT Manufacturing, Infrastructure, and Performance

Table 2.6 JIT Manufacturing, Infrastructure, & Performance (reference: Sakakibara, Flynn, et. al. 1997)	
Hypothesis Statement	Conclusion
H1: There is no relationship between JIT practices and manufacturing performance.	No statistically significant canonical pairs – thus not sufficient evidence to establish a link between JIT practices and manufacturing performance. Comment: maybe due to overly narrow 'JIT' construct.
H2: There is no relationship between infrastructure practices and JIT practices.	Thus strong relationship between infrastructure practices and JIT practices. Canonical pairs were statistically significant which indicated that over half the variance in JIT practices can be explained by infrastructure variables.
H3: There is no relationship between the combination of JIT practices with infrastructure practices and manufacturing performance.	Overall, the notion that a variety of practices are related with manufacturing performances. The practices most strongly related to manufacturing performance were manufacturing strategy, quality management, workforce management.
H4: There is no relationship between infrastructure practices and manufacturing performance.	The analysis indicates that manufacturing performance can be explained by the five infrastructure practices without considering JIT practices.
H5: There is no relationship between manufacturing performance and competitive advantage	Reject the hypothesis and conclude that analysis indicates there is a strong relationship between manufacturing performance and the entire set of competitive variables.

Henderson, et. al. (2004) study the impact of integrated manufacturing (IM) on non-financial performance and return on investment. The authors use the term "advanced manufacturing technology and information technology" (AMT-IT). This refers to the implementation of such technologies as CAM, CAD, CNC, which all have information technologies embedded. This is synonymous with what other researchers simply refer to as advanced manufacturing technologies (AMT). The authors' use of the term, integrated manufacturing (INTMFG), refers to the combination of AMT&IT, JIT, and TQM. "Combining the three – AMT&IT, JIT, and TQM – enables a streamlined value added system capable of converting raw material into finished goods, nominally interrupted by moving storage, or re-work."[76] The term "skilled use" is very interesting. Obviously, it is an important concept important but difficult to assess through a survey instrument. Many will state they have implemented SMED, TPS, TQM, etc. When in reality they perhaps have done some work in that arena but far fall short of "skilled use."

Table 2.7

Henderson's Integrated Manufacturing & Performance

(Reference: Henderson, et. al., 2004)	
Hypothesis Statement	Conclusion
H1: The skilled use of integrated manufacturing has a positive direct effect on non-financial manufacturing performance.	Supported, skilled use of INTMFG has an effect on non-financial manufacturing performance.
H2: Non-financial manufacturing performance has a positive direct effect on ROI.	Supported, non-financial manufacturing performance has an effect on ROI.
H3: In addition to an indirect effect through non-financial performance, the skilled use of integrated manufacturing has a positive direct effect on ROI.	Not Supported, skilled use of INTMFG has a negligible effect on ROI.

[76] Henderson, S. C. , Swamidass, P. M., Byrds, T. A. "Empirical Models of the Effect of Integrated Manufacturing on Manufacturing Performance and Return on Investment." International Journal of Production Research; 15 May 2004, Vol. 42, No. 10. 1933-1954.

Hendersen, et. al. (2004) conclude the following.

- "Skilled use of hard and soft technologies produces significant improvements in a composite of non-financial manufacturing performance." [77]
- "In the evaluation of manufacturing technology investments that contribute to integrated manufacturing, non-financial strategic issues such as cycle-time reduction, product line increase, and cost reduction must be included with traditional ROI-based justifications."[78]
- *"There is not a single combination of technologies that would benefit all manufacturers….* In this new era of integrative and strategic benefits of technologies, it may be appropriate to consider several matching technologies simultaneously for investment."[79]

Ketokivi and Schroeder (2004) provide insight into the published research by arguing for the inclusion of strategic contingency variables. Fundamental to their premise is that the effect of particular manufacturing practices on performance is contingent upon the strategic importance that the firm places upon the practice. Also they argue strongly in favor of treating manufacturing

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[77] Henderson, S. C. , Swamidass, P. M., Byrds, T. A. "Empirical Models of the Effect of Integrated Manufacturing on Manufacturing Performance and Return on Investment." International Journal of Production Research; 15 May 2004, Vol. 42, No. 10. 1948.

[78] Henderson, S. C. , Swamidass, P. M., Byrds, T. A. "Empirical Models of the Effect of Integrated Manufacturing on Manufacturing Performance and Return on Investment." International Journal of Production Research; 15 May 2004, Vol. 42, No. 10. 1949.

[79] Henderson, S. C. , Swamidass, P. M., Byrds, T. A. "Empirical Models of the Effect of Integrated Manufacturing on Manufacturing Performance and Return on Investment." International Journal of Production Research; 15 May 2004, Vol. 42, No. 10. 1949.

performance as a multidimensional response variable. Many of the previous studies collapsed multiple levels of performance into one a single overall measure of performance, which may be averaged across multiple dimensions. This method of treating multidimensionality of manufacturing response is not appropriate according to these authors. Based upon an extensive literature review, the following performance measures were used in this study: cost, quality, speed, deliver, volume flexibility, design flexibility. See Table results found in Table 2.8

The authors test their hypothesis by empirically investigating the importance of practice and the interaction of practice and relative strategic importance. This is accomplished through the development of separate ordinal regression models for each of the six performance measures (cost, quality, speed, deliver, volume flexibility, design flexibility). The survey was conducted using data from 164 companies from five countries (Germany, Italy, Japan, UK, USA). Ketokivi and Schroeder's findings include the following. [80]

- JIT is related to the performance areas of fast deliveries, low cost, and low cycle times.
- Cross functional cooperation is associated with conformance quality.
- Design for manufacturability is primarily associated with fast delivery and low cycle times.
- "Cross training the employees is related to faster delivery performance, but only if the plant is trying to implement a fast delivery strategy."[81]

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[80] Ketokivi, M., Schroeder, R., "Manufacturing Practices, Strategic Fit and Perfromance: A Routine-Based View", International Journal of Operations and Production Management, Vol. 24, No. 2, 2004, pp. 182-183.

[81] Ketokivi, M., Schroeder, R., "Manufacturing Practices, Strategic Fit and Perfromance: A Routine-Based View", International Journal of Operations and Production Management, Vol. 24, No. 2, 2004, pp. 182-183.

- Strong relationship between the effect of SPC on conformance quality, but only in those plant's that place a high priority on quality.
- Cross functional cooperation and long term supplier relationships were related to increased levels of conformance quality as was the use of SPC, but only if the firm placed a high level of importance on improving quality.
- Cross training of operators and JIT practices both were related to achieving gains in lowering cost.
- Cross functional cooperation was significant in terms of achieving design flexibility, but only in the presence of a strategic commitment to design flexibility.
- Only JIT was related to more than two dimensions of performance.

The study concludes " … manufacturing operations and practices are indeed strategic, that they are few best practices in the sense that they contribute to the competitive manufacturing performance in multiple dimensions." … "Incorporating strategic priorities into the analysis has provided us with a better understanding of the practice-performance relationships. The evidence shows that some practices are better suited to some strategies than to others."[82]

Ketokivi and Schroeder's work is particularly important to this research. Their work indicates that one set of best practices does not fit all situations. Notice several control factors were significant (plant size, age, country, …). This helps validate one of the fundamental assumptions that this research is built from and that is that the particular set of best practices

[82] Ketokivi, M., Schroeder, R., "Manufacturing Practices, Strategic Fit and Perfromance: A Routine-Based View", International Journal of Operations and Production Management, Vol. 24, No. 2, 2004, pp. 182-185.

needs to be tailored for the current situation the manufacturing firm finds itself facing. Hence, they have defined the need for carefully defined assessment methodology.

Table 2.8

Ketokivi and Schroeder's Goal-Practice-Performance Relationships

Performance Aspect	Significant Model Terms		
	Practice	Contingency: Practice*Strategy	Control
Low Cost	+XT +JIT		-Plant Age
Conformance Quality	+XC +SCR	+SI*SPC	+Market Share
Fast Delivery	+DFM +JIT	+SI*SCR	+Market Share +Process Choice
Cycle Time	+DFM +JIT		
Design Flexibility		+SI*XC	-Plant Age +Country
Volume Flexibility			+Process Choice

Manufacturing Practices

- XT – Cross Training
- JIT – Just in Time Manufacturing
- XC – Cross Functional Cooperation
- SI – Strategic Importance
- SCR – Supply Chain Relationships over the long term
- SPC – Statistical Process Control
- DFM – Design for Manufacturability
- PE – Proprietary Equipment

Control Factors

- Country of Operation
- Plant Size
- Plant Age
- Market Share
- Process Choice

+ Significance judged at $p < 0.05$

The authors claim that the literature often groups AMT into two categories: hard side and soft side. This research considers AMT to consist of the following hard-side technologies; computer numeric control (CNC), automated material handling (AMH), computer aided design and computer aided manufacturing (CADCAM), flexible manufacturing systems (FMS), automated guided vehicles (AGV), computer aided testing CAT), computer aided engineering (CAE). The soft-side AMT technologies (e.g., DFM, cellular manufacturing, JIT, …) were considered to be contingency variables.

Table 2.9

Das et. al.'s Contingency Variables in Linkage of AMT to Performance

Reference Das et. al. 2003		
Market/Product Environmental	*Lean Manufacturing*	*Work Organization*
• Plant sales • Business Strategy • Competition • Unionization • Production Policy (MTO/MTO) • Product Life Cycle Stage	• *JIT Supply* • Preventative Maintenance • *Set-up Time Reduction* • Group Technology • *Kanban*	• *Decentralized Decision Making* • *Work Teams* • *Worker Cross Training*
Note: italics indicate significant variables.		

This research considered lean manufacturing practices and work organization practices to be the primary contingency variables, environmental variables were thought to be of secondary importance.

Das et. al. (2003), after a review of other works, settle on the following dimensions of manufacturing performance: cost reduction, customization, delivery speed, manufacturing cycle time reduction, quality conformance, and new product introduction time reduction.

Table 2.10

Das et. al.'s Findings: Contingency Variables, AMT, and Performance

Reference Das et. al. 2003	
Hypothesis Statements	*Conclusion*
H1: "All 14 of the contingency variables to be examined are of significance. That is plants that differ on these variables will also differ in how their AMT investments are associated with manufacturing performance.	Partially Supported – set of lean variables "emerged at the top." JIT Supply followed by set-up reduction practices and Kanban.
H2: "Work organization practices are the most significant contingency variable, followed by lean manufacturing practices.	Supported – clearly subordinate role to lean practices. Largest effect among work organization practices was decentralized decision making. Also operator teams and cross training were significant.
H3: The 14 contingency variables fall into the following rough categories as to their expected importance.	Partially Supported

The detail analysis revealed some very interesting results, which are summarized below. Since the effects of individual contingency variables were not the goal of this study, these results were noted, but further investigation was not conducted. [83]

- "CAD appeared to have an across the board negative impact on manufacturing performance. Possible explanation is that designers have been found to use CAD to introduce new complexities in product design, stressing elegance at the expense of manufacturability and component costs."

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[83] DAS, A, Jayaram, J. "Relative Importance of Contingency Variables for Advanced Manufacturing Technology", International Journal of Production Research, 2003, Vol. 41, No. 18, pg. 4445.

- "CAE appears to be particularly effective at low levels of lean practices such as set-up time reduction, kanban, and JIT Supply."
- "A similar surprisingly positive strong effect of CAE was seen at low levels of employee cross training and use of operator teams."
- "Also interesting was the increased positive impact of CNC and CAE in an environment of high unionization."
- Plants with low levels of Kanban had a higher association between AMT's such as CAE and AMH, and manufacturing performance.

The authors conclude with the following. "It is apparent that the influence of AMT on manufacturing performance depended on the extent of leanness exhibited by the plant. Complementing this lean structuring or lean initiatives were work practices. Considering these two effects together, the findings suggest that plants which combine lean initiatives and work organization structures exhibit a higher variance in manufacturing performance that can be traced to AMT deployment."[84]

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[84] Das, I. A., Jayaram, J. "Relative Importance of Contingency Variables for Advanced Manufacturing Technology", International Journal of Production Research, 2003, Vol. 41, No. 18, pg. 4429.bid, pg. 4447

Table 2.11

Small's Linking AMT Portfolios to Manufacturing Performance

Reference Small, 1996	
Performance Attributes	*Technology Portfolio*
Labor Based • # of operators • Labor cost • Operator output rates • Tasks/Operator Time Based Operational • Delivery LT • Setup Time • Changeover Time • Manufacturing LT Time Based Product Development • Engineering/Design LT • Time-to-Market • Time to Complete Major Design Change Range Based Flexibility • Variety of Products Manufactured • Ability to Change Lot Size Quality Criteria • Product Quality • Scrap and Rework	Integrated Process and Information/logistics Technologies [INT (P+I/L)] • CAD/CNC • MRP • JIT • FMS • CIM • Robots Integrated Information/Logistics Technologies [INT (I/L)] • CAD/CNC • MRP • JIT Non-Integrated Technologies [NINT] • CNC/CAD

Small's 1996 survey of manufacturing enterprises focused on relating a portfolio of advanced manufacturing technologies relative to perceived performance in manufacturing.

Table 2.12

Small's Findings: AMT Technology Portfolio and Manufacturing Performance

Reference Small, 1996	
Research Questions	*Conclusion*
Q1: Are AMT Users experiencing improvements in performance on the manufacturing performance attributes covered in this study regardless of their extensiveness?	"Therefore, firms with more extensive systems appear to be achieving improvements in performance across a wider range of variables than those with systems that are less extensive."[85] Majority of INT (P+I/L) users reported improvements in 14 out of 15 performance attributes. Majority of INT(I/L) users reported improvements in 10 out 15 attributes Majority of NINT users reported improvements in 7 out of the 15 attributes.
Q2: Is there a relationship between extensiveness of the AMT portfolio adopted by a firm and the level of performance of the firm on each of the manufacturing performance attributes?	A significant relationship was found to exist between extensiveness of technology adopted and only three of the manufacturing performance attributes. • Ability to change production lot sizes • Worker productivity • Delivery lead-times
Q3: Compared with other AMT users, are firms with more extensive AMT portfolios achieving higher levels of performance on the manufacturing attributes covered in this study?	Significant differences were only found in 4 of the 15 attributes in terms of testing the claim that higher levels of performance are associated with more extensive users of AMT. • The performance of INT(P+I/L) was greater than INT(I/L) on higher levels of changeovers, ability to change lot sizes, and average # of tasks per operator. • The performance of INT(I/L) was greater than NINT firms on average # of tasks/operator, delivery LT, and ability to change lot sizes

MacDuffie at. al. 1996 work studied the impact of product variety on manufacturing performance within the global automotive industry. The ability to deal effectively with product variety has increasingly become a challenge for manufacturing firms across the world. For

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[85] Small, M. H. "Assessing Manufacturing Performance: An Advanced Manufacturing Technology Portfolio Perspective". Industrial Management & Data Systems; 1999, 266-277.

example, during a recent 15 year period the automotive market has seen a 70% increase in the number of different models and a corresponding 34% drop in average volume across model life. This study drew upon data, collected by MIT's IMVP program, from 70 assembly plants located throughout the world. Unlike most of the previous studies which rely upon perceptions of performance, this work relies upon actual plant data. Plant performance is measured based upon plant level productivity data and J.D. Power initial quality survey data of plant avoidable defects.

This work examines three types or dimensions of product variety: termed fundamental, peripheral, and intermediate. "One note on terminology, We use the term "variety" to refer to what the company wants to offer consumers- its product market strategy. These choices about the breadth and depth of different product lines affect manufacturing. We use the term complexity to refer to one dimension of the manufacturing task results from product strategy. Thus, a company's choice about product variety requires manufacturing plants to cope with a certain level of product mix complexity."[86]

The regression analysis focused on four measures of product complexity (i.e., model mix, parts complexity, option content, option complexity) and three control variables (automation level, scale of production, and product design age).

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[86] MacDuffie, John Paul, Sethuraman, Kannan, Fisher, Marshall L. "Product Variety and Manufacturing Performance: Evidence from the International Automotive Plant Study." Management Science, March 1996, Vol. 42, No. 3, pp 350-369.

Table 2.13

Productivity Using IMVP Automotive Assembly Plant Data

Reference MacDuffie et. al. 1996	
Variable	***Result***
Scale of Production	Not Significant
Automation Level	*-33.671 significant*
Product Design Age	*+ 1.044 significant*
Production Organization Index • Use of Buffers Index • Work System Index • HR Policies Index	*-0.129 significant*
Option Content	Not Significant
Model Mix Complexity	Not Significant
Parts Complexity	*+ 0.145 significant*
Option Variability Index	Not Significant
Note: significance judged at the 0.05 level	

Based upon the regression analysis on productivity, the significant independent variables were automation level, product design age, production organization index, and parts complexity. MacDuffie et. al. conclude the following.

- "We found that most of the product complexity measures did not have a negative impact on labor productivity or quality. The lack of any impact of model mix complexity may be due to the fact that plants (especially the body shops) are designed to handle a certain number of body styles and models."
- "The persistent and statistically significant negative effect of parts complexity on productivity is one of the most striking findings of this paper."

- “Our hypothesis that lean production policies give plants the capability to handle product variety more effectively was partially supported from an option content, with more mixed results from product complexity.”
- “These findings suggest that lean production policies such as Just-in-Time inventory systems; work teams, job rotation, and extensive training to develop a multi-skilled workforce; continuous improvement efforts involving production workers and engineers, …., and product development approaches can all play a role in helping “lean” plants absorb complexity successively.”
- “The argument here is that companies can invest in process improvements and other organizational capabilities that shift the trade-off point between cost and product variety considerably.”

The following Table 2.14 illustrates a summary of some of the most relevant findings regarding manufacturing performance and related factors.

Table 2.14

Summary of Literature: Influences on Manufacturing Performance

Paper	***Factors***	***Measurement of Performance***	***Findings***
Hendersen et. al., 2004	Advanced Manufacturing Technologies and Information Technology (AMT-IT). "Hard" – CAD, CAM, CNC "Soft" – JIT, Cells, SQC, TQM	Rating on scale Non-Financial Scale of 1-7 on 8 dimensions. ROI	• "Skilled use" of AMT-IT positively effect on a composite measure of non-financial performance. • Non-Financial manufacturing performance has a positive effect on ROI. • No evidence of a direct effect of AMT-IT on ROI.
Small, 1999	Technology Portfolio *INT(P+I/L):* CAD, CNC, MRP, JIT, FMS, CIM, Robots *INT (I/L):* CAD/CNC, MRP, JIT *NINT:* CNC/CAD	Rating on scale 5 Performance Attributes with 15 individual measures. Labor based, time based operational, time based product development, range based flexibility, quality criteria	• "Firms with more extensive use of AMT appear to achieve improvements in performance across a larger range of variables." • "Significant relationship was found to exist between extensiveness of technology and three performance attributes: ability to change lot sizes, worker productivity, delivery lead-times"
Flynn et. al. 1997	Infrastructure Practices Customer Relationships Supplier Relationships Workforce Management Quality Management Practices Design Process, Process Flow Management SQC & Feedback JIT Practices Kanban, Lot Size Reduction techniques Set-Up reduction Techniques JIT Scheduling	JIT Performance Avg. CT (receipt of raw material thru delivery) Quality Performance Perceived Market Outcomes, Final Pass Rate Competitive Advantage Low Cost, Fast Delivery Volume Flexibility Inventory Turnover, CT	• "Infrastructure variables alone were sufficient to predict JIT performance. Addition of JIT variables leads to further JIT improvements, but TQM variables did not." • Significant interaction variables led to the conclusion that "while quality and JIT function effectively in isolation, their combination yields synergies which lead to further performance." • "The plant's with the best quality performance are given an added boost through JIT's ability to pinpoint problems for subsequent resolution using quality management practices."
Sakakibara, et. al. 1997	JIT Practices Kanban, Lot Size Reduction techniques Set-Up reduction Techniques, JIT Scheduling JIT Infrastructure Product Design, Workforce Practices Organizational Characteristics Quality Management, Mfging Strategy	Manufacturing Performance Inventory Turnover On-Time Delivery Lead-Time Cycle-Time Competitive Advantage Overall Advantage Flexibility, Delivery Quality, Cost	• "Not sufficient evidence to link JIT practices and manufacturing performance." • "Strong relationship between infrastructure practices and JIT practices" • "Practices most strongly related to manufacturing performance were manufacturing strategy, quality management, and workforce management." • "Strong relationship between manufacturing performance and the entire set of variables that describe competitive advantage."

Table 2.14 Continued

Summary of Literature: Influences on Manufacturing Performance

Paper	***Factors***	***Measurement of Performance***	***Findings***
Das, et. al. 2003.	Environmental Variables Lean Mfging Practices Work Organization Practices "Hardside" AMT	Manufacturing Performance Cost reduction, customization, delivery speed, mfging CT reduction, quality conformance, new product intro LT.	• Significant relationship between contingency variables in explaining the relationship between AMT and performance. • Work organization variables were most important, followed by lean practices.
Gilgeous, 2001	22 different Improvement Programs	Manufacturing Capability Cost, Flexibility, Delivery, Service,	
Lowe, et. al. 1997	Plant location Plant Characteristics Inventories, Logistics, Internal Quality Human Resource Issues	Manufacturing Performance Productivity Quality Note : Actual plant data	• The effect of automation level depended upon the type of plant (e.g., seat, brake). • High performing plants appear to benefit from higher levels of integration and process discipline, as evidenced by lower WIP, and more frequent deliveries. • Higher performing plants are able to respond more quickly to changes requested by their customer. • No clear link between HR practices like teams and performance.
MacDuffie et. al. 1996	Various measures of Product Variety • Automation level • Product Design Age • Product Organization Index • Option Content • Model Mix Complexity • Parts Complexity • Option Variability Index	Manufacturing Performance Productivity Quality Note: actual plant data	• In general, product complexity measures did not negatively impact either quality or productivity. • Lean practices appear to enable manufacturing organizations to handle product variety and complexity without impacting performance.
Laugen, et. al., 2005	14 action programs (i.e., bundles of practice) Process equipment, capacity, automation, e-business, supplier strategy, outsourcing, *process focus, pull production*, quality management, *equipment productivity*, workplace development, ICT, NPD, *environmental.* *Significant practices*	17 measures (Likert scale: 1-5) collapsed into the following. ▪ Cost ▪ Quality ▪ Flexibility ▪ Speed	• Best practices: process focus, pull production, equipment productivity, environmental capability. • Quality and ICT are found to be former best practices that now do not differentiate between high and low performing firms – but are routine practices.

2.3 Manufacturing Taxonomies

A variety of works have attempted to classify manufacturing organizations. Perhaps the most influential framework was the product-process matrix published by Hayes and Wheelwright (1979). This allows the manufacturer to strategically align their manufacturing process approach with a characterization of the product life cycle.

Hayes and Wheelwright's (1978) seminal paper on manufacturing strategy extended the product life cycle concept, popular in the marketing literature, to what they refer to as the process life cycle. Similar to the product, the manufacturing process evolves over time to support the market requirements of the product. The interaction of product life cycle and process life cycle concepts is illustrated in what the authors term the product-process matrix.[87] This matrix is shown in the Figure below. This construct or taxonomy, has found its way firmly in the operations management research body of work. Several works have attempted to find empirical evidence of this classification scheme. The rows of the matrix illustrate major steps a production process tends to take. Early in the process life, the process is highly flexible, but not cost effective. As the process matures in its life cycle it tends toward increased standardization and automation: resulting in a highly efficient though capital intensive process.

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[87] R.H. Hayes, S.G. Wheelwright, "Link Manufacturing Process and Product Life Cycles," Harvard Business Review, 57 (1), 1979a, pg. 134.

Process Structure	Product Structure			
	I. Low Volume, low std., one of a kind	II. Multiple Products, low volume	III. Few major products, higher volume	IV. High Volume, high std., commodity
I. Jumbled flow (Job Shop)	Commercial printer			
II. Disconnected Line (batch)		Heavy Equipment		
III. Connected Line (assembly line)			Automobile Assembly	
IV. Continuous flow				Sugar Refinery

Figure 2.2 Hayes and Wheelwright's Product Process Structure

The authors contend that the product-process matrix can be helpful to firms as they develop an overall manufacturing strategy. This work is a clear example of the development of a manufacturing taxonomy and how it might be used to formulate strategy. Hayes and Wheelwright argue that a firm "can be characterized as occupying a particular region in the matrix, determined by the stage of the product life cycle and its choice of production process for that product."[88]

The upper left hand corner of the diagonal represents firms that offer a wide variety of products, which result in a process requirement that uses general equipment with jumbled flow paths (i.e., job shop). In addition, they contend "equipment is seldom used at 100% of capacity, the workers have a wide range of production skills, and each job takes much longer to go through the plant than the labors hours required."[89]

Further down the diagonal, the process is termed a disconnected flow line. While a number of products can be produced, the economies of scale lead these firms to consolidate their

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[88] Ibid, pg. 134

[89] Ibid, pg. 134

offering into basic models which possess a variety of options. The next level down the diagonal, a firm will decide to choose to make only a relatively few models and use a connected line (e.g., mechanized assembly line). However, the product demand must be sufficient to justify the increased investment. The far right hand corner of the diagonal represent those situations where the product is a commodity and the process is continuous. An example of this is refinery operations. These processes are highly automated, inflexible, and capital intensive.

Hayes and Wheelwright state that the process-product matrix can be helpful for firms when making decisions about how to organize their manufacturing operations. "The choice of product and process structures will determine the kind of manufacturing problems that will be important for management." This suggests that if we can identify where a manufacturing enterprise fits within the taxonomy, then they will tend to have similar types of core problems. This is one of the foundational premises that form the basis for this research.

Also Goldratt's VAT analysis has been recommended by some (Cox and Spencer, 1998) as a means to understand the structure of manufacturing and performance. The VAT classification scheme is a logical representation of the firm's product-process structure.

Table 2.15

Goldratt's V-A-T Classification Scheme

Product-Process Structure	*Characteristics*	*Typical Problems*
V	Condition where multiple end items are manufactured from the same raw material. Control points: • Divergent point • Constraint Example: Plumbing tube	Often misallocation occurs of materials occurs to reduce set-up and increase departmental efficiencies.
A	Numerous combinations of activities that are required to provide relatively few finished products. Points of convergence (like T) but additional processing required. Wide variation in sequences and routings. Control points: • Divergent point • Constraint Example: Jet Engine	Significant amount of expediting. Constraint is difficult to identify. Misallocation at convergent points (e.g., assembly).
T	Situation where numerous combinations of finished products result from a limited number of similar process steps. Control Points: • Constraint – controls throughput • Convergent point – controls allocation. • Gateway – controls WIP Example: Office Seating	Excessive WIP and Finished Good inventory. Misallocation of a common assembly from one product to another. Expediting in reaction to misallocations and long LT's due to high levels of inventory.

Miller and Roth's (1994) focused on developing a taxonomy for classifying manufacturing strategies. They found empirical evidence supporting the presence of three types of manufacturers from the standpoint of manufacturing strategy. These were termed "caretakers", "marketers", and "innovators." Also this work found that market scope and market differentiation were important underlying dimensions.

According to Miller and Roth (1994) various taxons or classification variables have been used within the overall strategic management literature. These include, but are not limited to, the following: descriptions about environment, technology, product life cycle, degree of uncertainty, scope of business, resource allocation patterns, degree of competition, behavior with respect to competition. The taxonomies previously identified in the literature were conceptual and not empirically defined.

Table 2.16

Miller & Roth's Taxons on Competitive Capability

Taxon	*Definition: Capability to ...*
1. Low Price	… compete on price
2. Design Flexibility	… make rapid design changes and/or introduce new products quickly.
3. Volume Flexibility	… respond to swings in demand.
4. Conformance	… offer consistent quality
5. Performance	… provide high performance products
6. Speed	… deliver products quickly
7. Dependability	… deliver on time (as promised).
8. After the Sale Service	… provide after the sale service
9. Advertising	… advertise and promote the product
10. Broad Distribution	…distribute the product broadly.
11. Broad Line	… deliver a broad product line.

Manufacturing executives in the study was asked to rate the relative importance of each competitive capability measure on a seven point, self anchoring scale. Three distinct strategy groups or clusters were identified through a multivariate clustering technique.

Cluster 1 – “Caretakers”

- Relatively low emphasis on competitive capabilities
- Price is the dominant competitive capability
- After sale service is significantly less important.

Cluster 2 – “Marketeers”

- Seeks broad distribution, offer broad product lines
- Values responsiveness to changing volume requirements
- Shared the relative importance with cluster 3 of conformance quality, dependable deliveries, product performance.

Cluster 3 – “Innovators”

- Differentiated by their emphasis on ability to make changes in design quickly.
- Value rapid new product introductions.
- Shared the relative importance with cluster 3 of conformance quality, dependable deliveries, product performance.
- Price is less important

Since many of these eleven taxons were highly correlated, a multivariate discriminate analysis was performed in order to identify underlying dimensions. Two underlying constructs or dimensions were found. These constructs were interpreted as “market differentiation” and “market scope.” The “market differentiation” dimension reflects the degree to which a firm places emphasis on its product and services in order to differentiate its offerings from the competition (i.e., relative importance of product performance, conformance quality, and after sales service). The "market scope" construct indicates the volume of customer base served by the business. This dimension refers to strong positive coefficients on broad distribution and volume flexibility, and negative relationship with design flexibility.

Table 2.17

Taxonomy of Manufacturing Strategy

	Underlying Dimensions: Discriminate Analysis	
Cluster	*Market Differentiation*	*Market Scope*
Caretakers	Less likely to value differentiating products and services – *low end of scale.*	Generally toward the end of product life-cycle – *low end of scale.*
Marketeers	More likely to place importance on product attributes – *high end of scale.*	Due to broad distribution emphasis - *high end of scale.*
Innovators	More likely to place importance on product attributes – *high end of scale.*	Emphasize product changes and flexibility – *low end of scale.*

In addition, the survey asked respondents to assess a list of 36 key action programs relative to their ability to improve the performance of their operations over the next two years. The action programs are a reflection of manufacturing choices.

- "The innovator's manufacturing strategy choices place significantly more emphasis on programs that promise to shorten total product cycle times…. "Innovators also focus on computer aided design (CAD), and emphasize developing new processes for their products. …"Innovators plan to embark upon manufacturing programs that reduce their manufacturing lead-times."[90] These choices appear to be consistent with an overall strategy that values the ability to rapidly change designs and introduce new products.

- Marketeers plan on focusing on infrastructural changes that cut costs and improve quality. They will focus on changing management/labor culture, and are apt to work in quality improvement programs. These changes are in alignment with fairly standardized processes and products.
- Caretakers apparently have placed their focus on price and have relatively low interest on improvement programs.

[90] Miller, Jeffrey G., Roth, Aleda V., "A Taxonomy of Manufacturing Strategies", Management Science, Vol. 40, No. 3, March 1994, pp 297

Table 2.18

Strategy and Context by Cluster

	Cluster		
Programs	*Caretakers*	*Marketeers*	*Innovators*
Labor/Management Relationships	4.28	5.10 (3)	4.29 (2)
Zero Defects	4.28 (2,3)	5.43 (1)	5.35 (1)
Mfg LT Reduction	4.33 (3)	5.16	5.56 (1)
CAD	3.53 (2,3)	4.99 (1)	5.14 (1)
New Process/New Product	4.06	5.03	5.05
Closing Plants	2.00	2.91 (3)	2.11 (2)
SPC (Process)	4.61 (2)	5.79 (1, 3)	5.11 (2)
SPC (Product)	4.39 (2)	5.43 (1)	4.89
New Product Introductions	3.76 (2,3)	5.06 (1)	5.42 (1)
Reducing Size of Workforce	3.83	4.83 (3)	3.89 (2)

Values represent mean scores. Numbers in parenthesis indicate group(s) that are significantly different
Shading indicates significant differences.
Scale: 1= very unimportant, 7=very important
Note: Out of a total of 36 key action programs, 10 variables were found to be significant and are summarized in the table above.

Sum, et. al. (2004) develop an empirically defined taxonomy of operations strategy based on evidence within Singapore's high performing small and medium size manufacturers. Similar to Miller and Roth, Sum found three clusters of firms analogous to Miller and Roth's study. These clusters were labeled "all-arounders", "efficient innovators", and "differentiators." Sum et. al., notes that a taxonomy, through its clustering of similar operations and goals, gives us a strong approach for describing and tracking how SMEs readily adapt priorities (e.g., cost, quality, delivery) in response to changing environments.

Sum, et. al. mentions that there is a "lack of operations strategy literature on the development of taxonomies and typologies." [91] "The paucity of attention given to the understanding of operations strategy of small and medium sized enterprises (SME), especially successful ones, is unfortunate as SME'a exert a strong influence on the economies of many countries… Furthermore, the operational characteristics of flexibility, innovativeness, nimbleness, and quick problem solving orientation found in successful SMEs represent vital ingredients for corporate success regardless of firm size."[92] Other conclusions supported by Sum et. al. 2004.

- Support is evidenced that different strategic clusters emphasize and adopt different programs to improve operational performance.
- Efficient innovators reported the highest overall financial performance, growth in sales, and growth in market share.
- "Our analysis indicates that high performing enterprises compete effectively on multiple priorities simultaneously. …. This finding, that enterprises can compete effectively on multiple priorities." [93]

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[91] Miller, Jeffrey G., Roth, Aleda V., "A Taxonomy of Manufacturing Strategies", Management Science, Vol. 40, No. 3, March 1994, pp 323

[92] Sum, C.C., Kow, L.S., Chen, C.S., "A Taxonomy of Operations Strategy of High Performing Small and Medium Size Enterprises in Singapore", 2004, International Journal of Operations and Production Management, 2004, Vol. 24, No. 3, pp. 322.

[93] Sum, C.C., Kow, L.S., Chen, C.S., "A Taxonomy of Operations Strategy of High Performing Small and Medium Size Enterprises in Singapore", 2004, International Journal of Operations and Production Management, 2004, Vol. 24, No. 3, pp. 340

- A critical aspect of the process in developing operations priorities is discerning the types of improvement programs and initiatives that will match objectives.

Table 2.19

Strategic Clusters and Future Programs of High Performing SMEs

	"All-Rounders"	*"Efficient Innovators"*	*"Differentiators"*
Current Programs	ISO 9000 Worker Skill Training Cost Reduction	Cost reduction JIT Worker Skill Training Automation Improve Capacity	ISO 9000 Cost Reduction
Future Programs	Worker Skill Training Cost Reduction Implementing TQM Seek New Markets	Cost Reduction Worker Skill Training JIT Automation E-Commerce Improve Capacity Adoption of IT Systems Better Forecasting Systems Business Process Re-engineering Benchmarking Implementing TQM Seek New Markets	Cost Reduction ISO 9000 Worker Skill Training JIT Improve Capacity Adoption of IT Systems Business Process Re-engineering Benchmarking Implementing TQM Seek New Markets

Kathuria (2000) develops an empirically defined taxonomy based upon his survey of small manufacturers. This taxonomy is based primarily on how the firm relates to what the author defines as competitive priorities (e.g., quality, delivery, flexibility, and cost). Multivariate analysis produced four clusters: "starters", efficient conformers, speedy conformers, and "do all."

Kathuria's work suggests "different manufacturers use different basis to compete in the same industry."[94] This implies that different firms may pursue totally different strategies and yet be equally effective. Also, there appears to be some evidence of Ferdow's and De Meyer's "sand cone" model in the four clusters. The foundational layer is being developed by the "starters" and the highest layer is evidenced by the "do alls."

Morita and Flynn's (1997) survey compared three types of firms (world class, emerging world class, and random sample) in terms of the extent of their dependence on the 11 characteristics. This resulted in the "world class" group showing a significantly higher reliance than upon each of these management characteristics than the "emerging world class" group. The "emerging world class" firms showed a significantly greater reliance upon these management characteristics than did the "random sample" firms. Cluster analysis was used to determine whether certain characteristics tended to cluster together. The result was that three clusters were identified: strategic focus, operations management, and quality management.

[94] Kathuria, R. "Competitive Priorities and Managerial Performance: a taxonomy of small manufacturers", Journal of Operations Management, 2000, Vol. 18, pg.638.

[94] Bolden R., Waterson, P., Warr, P., Clegg, C., Wall, T., "A New Taxonomy of Modern Manufacturing Practices, International Journal of Operations & Production Management, 1997, Vol. 17, No. 11, pp. 1114.

Table 2.20

Cluster of Characteristics/Practices

Reference: Morita and Flynn (1997)		
<u>Strategic Focus</u> • Strategic Adoption • Management Practices • Technological Adoption	<u>Operation Management</u> • Production Control System • Working on the Floor • Production System	<u>Quality & HR Management</u> • Organizational System for Quality • Operational System for Quality • Human Resource Development • Commitment Pride in Work

Of particular relevance to this research is the work of Bolden, et. al., (1997). This publication makes a substantial contribution to the subject of manufacturing taxonomies. Their work focuses on developing a taxonomy of best practices. The authors state that one of the biggest challenges to characterizing the relationship between practices and performance is the inconsistent and vague definitions of "best practices." During their literature review they note variations in terms, degree of specificity, and conceptual differences are common in publications dealing with best practices. For example, some authors identify a specific tool (e.g., SPC) as a best practice, while others define a broader practice (e.g., TQM). Some researchers define advanced manufacturing technologies to include Japanese lean manufacturing practices, while others restrict the definition to "hard technologies" like automation, robotics, and CAD/CAM. "Our intention was to include practices of a similar level of specificity, which were not so specific as to potentially render them out of date within a few years (e.g., MRP I and MRP II) and not so vague as to make it difficult to relate to them in reality (e.g., manufacturing systems). "[95]

The benefits of a manufacturing practices taxonomy according to Bolden et. al. includes the following.

- Enables the identification of inter-relationships between practices in a clear manner.
- Assists in the identification of the differences and commonalities between practices.
- Enhances the identification of practices for researchers and practitioners from a variety of backgrounds.
- Promotes the identification of gaps between theory and practice.

Clearly many practices have multiple goals which supersede particular categories. “It is unlikely that any usable taxonomy of manufacturing practices can be entirely clear cut; instead one of the benefits of building such a framework is that it encourages further differentiation and clarification of the specific practices contained within it.”[96]

Bolden et. al., concluded that which best practices are investigated, in a particular study, appears to depend upon the academic background of the researcher. Therefore the sets of best practices which are studied tend to be incomplete and fragmented. For example, industrial psychologists tend to focus on such factors as corporate culture, work organization, and employee development; mostly ignoring traditional engineering topics. The engineering based research tended to focus on logistics, computer integrated manufacturing, cycle time reduction techniques; virtually ignoring the social science based factors. This situation has led the authors to conclude that in this field “multi-disciplinary collaboration, often called for, is still more of a pipe dream

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[96] Bolden R., Waterson, P., Warr, P., Clegg, C., Wall, T., “A New Taxonomy of Modern Manufacturing Practices, International Journal of Operations and Production Management, 1997, Vol. 17, No. 11, pp. 1123

than a reality."[97] This fragmentation, within the research community, results in what the author's term "omission of certain themes and a failure to regard the domain of manufacturing as a whole."[98]

The authors review of taxonomies of practices referenced in the literature resulted in their conclusion that none describe the full coverage of manufacturing practices in use. This work clearly states that "there remains a need for the development of taxonomy which provides an overview of the domain of manufacturing practices and is not blinkered by its disciplinary origin."[99]

This research presents a conceptual taxonomy of practices based upon interactions with a diverse set of inputs. The initial taxonomy was developed using input from researchers from a variety of perspectives, which included industrial psychology, manufacturing engineering, and management systems. The initial approach yielded a list of 70 itemized practices. However, the research team judged that this preliminary list was too abstract, or vague to be effective within a survey instrument. Therefore an extensive "key term" search was made within all the related research journals (both professional and popular). This review resulted in the list of practices expanding to 254 terms. Next the research team clustered similar types of activities, which produced 87 clusters of practices. These 87 practice clusters were placed within a matrix. The dimension of the matrix reflected the practice's "strategic emphasis" (i.e., why the practice is

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[97] Bolden R., Waterson, P., Warr, P., Clegg, C., Wall, T., "A New Taxonomy of Modern Manufacturing Practices, International Journal of Operations and Production Management , 1997, Vol. 17, No. 11, pp. 1112

[98] Bolden R., Waterson, P., Warr, P., Clegg, C., Wall, T., "A New Taxonomy of Modern Manufacturing Practices, International Journal of Operations and Production Management, 1997, Vol. 17, No. 11, pp. 1115

[99] Bolden R., Waterson, P., Warr, P., Clegg, C., Wall, T., "A New Taxonomy of Modern Manufacturing Practices, International Journal of Operations and Production Management, 1997, Vol. 17, No. 11, pp. 1114

used?) and "domain of application." (i.e., the part of the manufacturing practice primarily involved).

Classification of Manufacturing Practices

Reference Bolden, et., al., 1997

Strategic Emphasis

Business Focused – specific outcomes that are important to achieve a competitive advantage.

- Cost
- Quality
- Responsiveness

Organization Focused – more generic practices that target developing overall capability.

- Technology
- Employee Development

Note: It was recognized that some practices satisfy more than one objective. However, during the classification process the researchers attempted to include each practice within the single, most important dimension.

Domain of Application

Design and Production – references practices focused on product design (e.g., CAD) or manufacturing process (e.g., adherence to quality standards)

Inventory and Stock – refers to practices relating to purchasing, distribution, or warehouse management (e.g., ASRS).

Work Organization – describes the way the production area is organized and managed (e.g., cellular manufacturing).

Wider Organization of Manufacturing – refers to which are organization wide (e.g., lean). .

Figure 2.3 Bolden's Classification of Manufacturing Practices

The major focus of the taxonomy was not to determine the optimal placing of the practice within the taxonomy but to ensure that "all necessary practices and areas of manufacturing had been included."[100]

"The main objective of this development was to provide a multi-disciplinary overview of the field of manufacturing practices, which could guide selection of key practices for inclusion in studies by practitioners and academics….. Our intention was to include practices of a similar level of specificity, which were not so specific as to potentially render them out of date within a few years (e.g., MRP I and MRP II) and not so vague as to make it difficult to relate to them in reality (e.g., manufacturing systems). "[101]

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[100] Bolden R., Waterson, P., Warr, P., Clegg, C., Wall, T., "A New Taxonomy of Modern Manufacturing Practices, International Journal of Operations and Production Management ,1997, Vol. 17, No. 11, pp. 1119

[101] Bolden R., Waterson, P., Warr, P., Clegg, C., Wall, T., "A New Taxonomy of Modern Manufacturing Practices, International Journal of Operations and Production Management ,1997, Vol. 17, No. 11, pp. 1114

Table 2.21

Taxonomy of Manufacturing Practices

Problem Domain	*Strategic Emphasis*				
	Business Focus			Organization Focus	
	Improved Quality	Reduced Cost	Responsiveness to Customer	Improved Technology	Employee Development
Design and Production	Quality Standards SPC TPM QFD Poke-Yoke	Reduced WIP JIT Production Process Mapping Smart Design Re-usability Product Rationalization	Rapid prototyping Concurrent engineering Customer involvement in design LT reduction Agile manufacturing	CAPP CIM Automation CAD & engineering	Job Rotation Multi-Skilling Psychromterics Appraisal Training & development Suggestion schemes Attitude surveys Secondments Safety management
Inventory and Stock	Supply Chain Partnering Customer Feedback Conformance Checks	Reduced Inventory Single Sourcing JIT Inventory Control Forecasting Logistics Management	Predicting customer requirements Maintaining stock levels	Automated storage & retrieval systems EDI	Product team (purchasing and distribution)
Work Organization	Quality improvement teams Operator responsibility Quality feedback to operators Quality training Ergonomic design	Downsizing De-layering Outsourcing Casual labor	Flexible work organization After sales support Cellular manufacturing	FMS Group Technology Computer co-operative work MRP	Harmonization Team based work Job Enrichment Boundary Management
Wider Organization	Total quality management Quality awards Quality gurus World class manufacturing Benchmarking for quality	Lean production Cost management Financial performance Time based management Benchmarking: costs	Priority given to customers Market research Customer surveys Benchmarking for customer responsiveness BPR	Technology strategy Computer based management tools Benchmarking for technology	Explicit company HRM strategy Empowerment Performance based pay Culture change Learning climate Investors in people Bench people effectiveness

Other taxonomies were found on topics related to manufacturing. Gershenson and Stauffer's 1999 work focused on the use of taxonomies to classify customer driven design requirements. A taxonomy for the analysis of re-manufacturing industry practices was developed by Parkinson and Thompson 2003. The dimensions pertaining to manufacturing flexibility were classified according to a taxonomy developed by D'Souza and Williams, 2000.

White (1996) developed a taxonomy for categorizing performance measures. The purpose of the taxonomy is to distinguish between these measures and assist the practitioner in selecting the appropriate measure to support competitive strategy. This research concludes that while numerous authors are in agreement that "performance measurement is an important tool for making companies more competitive in the global market place. They argue that performance measurement serves not only as a scorecard, but also a compass that indicates direction for needed improvement in a company's manufacturing activities."[102] Therefore, thorough understanding of performance measurement characteristics is critical to the development of an overall assessment methodology. Using the taxonomy, he classifies measures as follows.

- Competitive Capability: Cost, Quality, Flexibility, Speed, Delivery Reliability
- Data Source: External or Internal
- Data Type: Objective or Subjective
- Reference: Benchmarked or Self Referenced
- Process Orientation: Input or Outcome.

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[102] White. Gregory P,. "A Survey and Taxonomy of Strategy-Related Performance Measures for Manufacturing", International Journal of Operations and Production Management, University Press, Vol. 16, No. 3, 1996, pp. 45.

2.4 Competing Production Systems

In terms of modern production system theories, this research asserts there are three main streams of thought: Toyota Production System (TPS), factory physics (FP), and theory of constraints (TOC). These concepts will be explored further on the basis that they represent important perspectives which need to be considered when prescribing recommendations for improved performance. Also, while differing in some aspects, they all challenge the traditional mass production paradigm. While not universally accepted, many researchers have adopted the term lean manufacturing to represent the leading prescriptions which lead to improved performance. Clearly, using this definition, all three perspectives fit under the banner of "lean manufacturing." "Lean manufacturing is not, as some researchers suggest, a generic term for the Toyota Production System (TPS). … Toyota was, however, the first company to incorporate lean principles as a coherent and clearly articulated system of production." [103]

The lean concepts, codified by Toyota in Japan during the 1960's and 1970's, have clearly made a profound impact on production system design and performance during the last couple of decades. In the opinion of this author, its impact on performance is difficult to over estimate. The theory of constraints, originated by Eliyahu Goldratt, is a relentlessly logical approach to diagnosing problems and developing powerful solutions to problems which confront manufacturers. The TOC, though not as popular as TPS, has attracted a devoted following among practitioners. Numerous case studies have been presented in the literature which clearly document substantial improvements in performance that have occurred due to the implementation of TPS, TOC, or both. Factory Physics, while not as well known among practitioners as the other

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[103] Standard, Charles, Davis, Dale, Running Today's Factory: A Proven Strategy for Lean Manufacturing, Hanser Gardner Publications, Cincinnati, OH., pg. 59

approaches, has made an important contribution to enhancing understanding about the fundamental dynamics within manufacturing systems. These concepts developed by Wallace Hopp and Mark Spearman, emerged out of the academic research community in an attempt to define the “science of manufacturing.”

2.4.1 Toyota Production System

Researchers and practitioners alike agree, the system of production developed and refined by post World War II Japan has had profound impact on manufacturing. This approach is termed the Toyota Production System (TPS), primarily because of the significant impact of Toyota on its development. Taiichi Ohno and Shigeo Shingo, under the management leadership of Eiji Toyoda at Toyota, are generally credited as TPS’s primary architects of TPS.[104]

Clearly several factors played a role in the development of TPS, including scarcity of resources, relatively dense concentration of manufacturing plants, and the low volume/high variety nature of the Japanese automotive market. The principal challenge that Toyota faced was how to compete with the American automobile industry, while serving a much smaller and more diverse automotive market. Therefore, Toyota could not rely upon economies of scale as the key enabler of increased productivity. This forced Toyota to seek other ways to reduce costs, leading to an intense focus upon the elimination of all forms of waste. The goal was to attain smooth

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104 Standard, Charles, Davis, Dale, Running Today’s Factory: A Proven Strategy for Lean Manufacturing, Hanser Gardner Publications, Cincinnati, OH., pg. 59

product flow, without the benefits of high levels of inventory (defined as waste). To attack this problem Ohno states that TPS rests upon two pillars:[105]

- Just-in-time flow of materials
- "Autonomation" or automation with a human touch.

Ohno's goal for material flow was for each work-center to receive product from an upstream work-center at the time needed, and in the quantity needed. The use of "kanban" signals was developed which ensured that the upstream workstations only produced in accordance with the need of the next operation. Overproduction was viewed as a form of waste, which must be eliminated; therefore, small production lots were desired. The challenge was how to reduce set-up times in order to enable small lot production in multiple product environments. The work of Shigeo Shingo, originally developed in the Japanese shipyard, was instrumental in minimizing disruptions in flow attributable to set-up delay. This approach is termed "single minute exchange of dies" (SMED). Of course, this requires a system with virtually no disruptions in terms of machine breakdown and product nonconformity. The idea of "autonomation" (or "automation with a human touch") refers to a level of automation that enables one operator to tend to multiple machines. These machines were "mistake proofed" so that problems were automatically detected and fixed as they occur. This resulted in drastically reducing the runs of poor quality products fed to downstream operations. The idea of "automation with a human touch" also impacts the idea of mistake proofing from the standpoint that the machine should trigger operator intervention at just the right time in order to prevent the production of a defect.

In addition to just-in-time and "autonomation", Monden (1983) adds the following additional pillars to TPS: flexible workforce and creative thinking.[106] Workers must have multiple

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[105] Hopp, Wallace, Spearman, Mark, Factory Physics: Foundations of Manufacturing Management, Second Edition, 2001, Irwin McGraw-Hill, pp. 152

skills so that proper responses are made in conjunction with changes in production volume. Also, the demand to eliminate all forms of waste requires the total commitment and involvement of the workforce. An active employee suggestion system with a high implementation rate is characteristic of the TPS approach.

Monden (1983) states in order for TPS to achieve the four TPS fundamental concepts (just-in-time, autonomation, flexible workforce, creative thinking) the following methods are advocated.[107]

1. Kanban system – to maintain just-in-time flow
2. Production smoothing – used to accommodate demand changes
3. Set-up time reduction – used to reduce manufacturing lead-time.
4. Work standardization – used to eliminate variability and achieve line balance.
5. Work areas designed to allow for multifunctional workers
6. Improvement activities are conducted by employees to reduce costs and improve morale.
7. Visual controls to implement autonomation
8. Promotion of company-wide total quality control

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[106] Monden, Yashiro, Toyota Production System, Industrial Engineering and Management Press, 1983, Norcross GA., pp. 2.

[107] Ibid.

The TPS philosophy was introduced in the United States in the early 1980's and became popularly identified as "just-in-time" (JIT) manufacturing. During the last 25 years, numerous works have been published introducing JIT to American manufacturing managers. The following review, while not exhaustive, provides an overview of some of the more influential publications.

Richard Schonberger's publication of his book Japanese Manufacturing Techniques in the early 1980's, and his later work entitled World Class Manufacturing have both reached large audiences with managers seeking to understand the principles of "just-in-time" manufacturing. Schonberger's works provide useful introductions to key elements of JIT, which he describes as world class manufacturing practices. These practices are often illustrated through presentation of actual cases and include such practices as such as SMED, Kanban, sole source suppliers, design for manufacturability, multi-skilled worker, cells, and operator involvement in problem solving. Also the link between JIT and TQM was emphasized. Schonberger was also one of the early advocates of lead-time reduction as a strategic measure of continuous improvement. He challenged companies to make order of magnitude improvements in quality and lead-time reduction. This resulted in publications of the "5-10-20" list which refers to organizations that achieved five fold, ten fold, or twenty fold reductions in manufacturing lead-time.[108]

Womack, Jones, and Roos in their 1991 publication The Machine that Changed the World published a detailed comparison between the performance of western and Japanese automotive plants. Much of the data published in this book stemmed from a 5-year international study of automotive assembly plants. This survey, led by MIT's International Motor Vehicle Program (IMVP), is considered the most comprehensive international study ever conducted in

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108 Schonberger, Richard, World Class Manufacturing: The Lessons of Simplicity Applied, 1986, The Free Press, New York, NY, pp. 4.

any industry.[109] The conclusion was striking; the performance of American and European plants, using mass production techniques, was clearly inferior to the performance of the Japanese plants. *In fact, it was in this context that the term lean manufacturing was first coined in an effort to accurately describe the Japanese practices*. "Lean production is 'lean' because it uses less of everything compared with mass production- half the human effort in the factory, half the manufacturing space, half the investment in tools, half the engineering hours to develop a new product in half the time. Also it requires keeping far less than half the needed inventory on site, results in many fewer defects, and produces a greater and ever growing variety of products."[110] The authors conclude "lean production combines the best features of both craft production and mass production- the ability to reduce costs per unit and dramatically improve quality while at the same time providing an ever wider range of products."[111]

Womack and Jones in their follow-up publication entitled Lean Thinking focused more on the underlying principles of lean both on the shop floor and across the enterprise. Applications of lean thinking are presented through case studies from Pratt & Whitney, Porsche, Showa, and Wiremold. The principles developed in this book focus first on contrasting the difference between waste (or in Japanese, "muda") with the concept of value, which is defined by the customer. "Value is produced by the producer. From the customer's standpoint this is why producers

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109 Womack, James, Jones, Daniel, Roos, Daniel, The Machine that Changed the World: The Story of Lean Production, 1990, Harper Perennial, New York, NY, pp. 75-76.

110 Womack, James, Jones, Daniel, Roos, Daniel, The Machine that Changed the World: The Story of Lean Production, 1990, Harper Perennial, New York, NY, pp. 13

111, Womack, James, Jones, Daniel, Roos, Daniel, The Machine that Changed the World: The Story of Lean Production, 1990, Harper Perennial, New York, NY, pp. 277.

exist."[112] They advocate a fundamental re-thinking of value from the customer's perspective. Companies are encouraged to eliminate all forms of waste throughout their operations. The value steam is defined as "the set of all specific actions required to bring a specific product (whether a good or service, or, increasingly a combination of the two) through the three critical management tasks of any business."[113] These tasks include engineering product design, order management, and the physical transformation task. Once value has been defined, and efforts are focused on eliminating waste, the next challenge is to establish a continuous flow of product; triggered by a pull signal from the customer. This process creates a never ending quest for obtaining perfection in the value proposition offered to customers. Womack and Jones summarize this in the following five principles of lean thinking.[114]

1. Specify Value
2. Identify the Value Stream
3. Flow
4. Pull
5. Perfection

One researcher noted that crucial to understanding lean thinking is the emphasis on value. "In 1996 Womack and Jones crystallized value as the first principle of lean thinking. As such, lean had moved away from a merely 'shop-floor-focus' on waste and cost reduction, to an

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[112] Womack, Thomas, Jones, Daniel, Lean Thinking: Banish Waste and Create Wealth in Your Corporation, 1996, Simon & Schuster, New York, NY., pp. 16.

[113] Womack, James, Jones, Daniel, Roos, Daniel, The Machine that Changed the World: The Story of Lean Production, 1990, Harper Perennial, New York, NY, pp. 19.

[114] Womack, James, Jones, Daniel, Roos, Daniel, The Machine that Changed the World: The Story of Lean Production, 1990, Harper Perennial, New York, NY, pp. 16-25

approach that contingently sought to enhance value (or perceived value) to customers by adding product or service features and/or by removing wasteful activities."[115]

Hines et. al. note that while clearly lean is the most influential new paradigm in manufacturing, you can form a strategic perspective to integrate it with other approaches (e.g., 6 Sigma, TOC, TQM, etc.) without compromising its core objective, which is to provide customer value. "These additional perspectives help to create a more well rounded and focused tool-set for applying lean in order to create capacity at the constrained resource."[116]

2.4.2 Factory Physics

Another important work, which has contributed greatly to the maturing of lean manufacturing concepts, is Hopp and Spearman's 1996 publication entitled Factory Physics. One author has labeled the factory physics approach as the "science of lean manufacturing."[117] Much of the earlier publications on lean rely heavily on good practices, actual experiences, rules of thumb, and overall philosophy; but largely ignore the mathematical basis which describe why these approaches appear to work well. The factory physics approach develops both descriptive and prescriptive mathematical models which characterize manufacturing operations. The ultimate

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115 Hines, P., Holweg, M., Rich, N., "Learning to Evolve: A Review of Contemporary Lean Thinking", International Journal of Operations and Production Management, Vol. 24, No. 10, 2004, pp. 995.

116 Hines, P., Holweg, M., Rich, N., "Learning to Evolve: A Review of Contemporary Lean Thinking", International Journal of Operations and Production Management, Vol. 24, No. 10, 2004, pp. 995 Ibid., 1007

117 Standard, Charles, Davis, Dale, Running Today's Factory: A Proven Strategy for Lean Manufacturing, 1999 Hanser Gardner Publications, Cincinnati, OH.. pp. 74.

goal is to develop a set of "manufacturing laws" which provide insight and build intuition regarding the challenge of manufacturing.

The models advocated within factory physics are relatively simple, rooted in the field of operations research and queuing theory. The ultimate objective is not to model each manufacturing facility in detail, but to build a linked set of basic models which may be used to build solid intuition when dealing with the problems of manufacturing.[118] This approach takes issue with the dominant manufacturing research community. Typically researchers have focused extensively on sequencing and scheduling of mostly deterministic and idealized problems, which one publication noted "offer little insight into a real factory, where variability is a constant."[119] The fundamental model which describes the basic dynamics of the manufacturing flow is Little's Law.

$$Throughput = \frac{WIP}{CT}$$

Definition of Terms

Throughput = rate of production

WIP = Work-In-Process

CT = Cycle Time

Figure 2.4 Little's Law

[118] Standard, Charles, Davis, Dale, Running Today's Factory: A Proven Strategy for Lean Manufacturing, 1999 Hanser Gardner Publications, Cincinnati, OH.. pp. 74. Ibid., pp. 74.

[119] Standard, Charles, Davis, Dale, Running Today's Factory: A Proven Strategy for Lean Manufacturing, 1999 Hanser Gardner Publications, Cincinnati, OH.. pp. 74. Ibid., pp. 75

Little's Law is very robust. It works regardless of the amount of variability that is present in the system. It is also works well at the local level (i.e., workstation level) and at more global levels (i.e., production system level). The factory physics laws identified by Hopp and Spearman are listed below.[120]

- *Little's Law:* TH = WIP/CT
- *Capacity:* In steady state all factories will release work at an average rate that is strictly less than average capacity.
- *Variability:* In steady state increasing variability always increases average cycle times and WIP levels.
- *Variability Placement:* Variability early in a routing has a larger impact on WIP or CT than equivalent variability later in the routing.
- *Utilization:* If a system increases utilization without making any other changes, average cycle times will increase in a highly non-linear fashion.
- *Move Batches:* Cycle-times over a segment of a routing are roughly proportional to the move batch sizes used over that segment.
- *Process Batches:* As process batch size increases, cycle time increases proportionately.
- *Pay Me Now or Pay Me Later:* If you cannot pay for variability reduction, you will pay in one or more of the following ways: 1). Long cycle time and high WIP levels, 2). Wasted capacity, 3). Decreased throughput

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[120]Standard, Charles, Davis, Dale, Running Today's Factory: A Proven Strategy for Lean Manufacturing, 1999 Hanser Gardner Publications, Cincinnati, OH.. pp. 74. Ibid., pp. 92-93

- *Lead Time:* the manufacturing lead time of a routing that yields a given service level is an increasing function of both the mean and variance of the cycle time for the routing.
- *Cycle Time:* The average cycle time for a routing is the sum of the average cycle times for the stations on the routing. For each station the average CT = queue time + process time + wait for batch time + move/transition time.
- *Self Interest:* People, not organizations, are self optimizing. Optimizing individual jobs does not optimize the factory.
- *Responsibility:* Responsibility with out commensurate authority is demoralizing and counterproductive.

In retrospect, some of the early authors described an idealistic approach to JIT (i.e, TPS) that relied much too heavily on platitudes and fuzzy rhetoric. According to Hopp and Spearman, some of the comments of early American authors in their zeal to motivate western manufacturers to adopt the JIT methodology were overly simplistic in their description and often downplayed the difficulties associated with implementation. Hopp and Spearman describe this as romantic JIT.

According to Hopp and Spearman, one of the challenges in evaluating the romantic JIT writings in an effort to develop a coherent system, is how to deal with the challenge of multiple objectives. According to Schonberger, the concept of trade-offs is a myth and should be jettisoned. In earlier works, he mentions that the word trade-off should be banned from civil discourse. In sharp contrast, Hopp and Spearman assert that understanding trade-offs is essential to developing intuition about the challenge of manufacturing. They state that in the real world of manufacturing, firms face trade-offs all the time. "Throughput, quality, regular flow, lower inventory, high service levels, flexibility, reduced costs, and many others are all legitimate, though at times conflicting objectives. Romantic JIT advocates do not provide insight into which objective takes precedence. Hopp and Spearman argue that the originators did make trade-offs, though in a very clever and artful manner. "The subtlety of the Japanese system for making trade-offs allowed it to be easily overlooked, and consequently this aspect of JIT was lost in popular descriptions of it."[121] In fact, some of the ambiguity in the early understanding of JIT, is attributable to the Japanese founders deliberately using confusing terms. Ohno is quoted as saying "If the U.S. had understood what Toyota was doing, it would have been no good for us."[122]

Hopp and Spearman in their critique of the early JIT advocates state the following. "The books of Hall (1983), Monden (1983), Shingo (1989), and Schonberger (1982, 1983) are replete with detailed descriptions of mechanical devices, plant layouts, and organizational structures with which to implement JIT. It is from this smorgasbord of techniques that practitioners were to achieve the environment of continuous improvement called for in romantic JIT…. To choose appropriate pragmatic JIT methods and construct a coherent set of operating policies require a huge creative effort on the part of the practitioner." Hopp and Spearman state that the "failure of the American JIT literature to develop the intuition and systematic framework needed for balancing competing objectives was a serious one."[123]

The factory physics approach largely confirms the performance improvement that is enabled by the principles of lean manufacturing. However, the major contribution of the factory physics approach is that it provides a general framework and seeks to understand at a more

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[121] Hopp, Wallace, Spearman, Mark, Factory Physics: Foundations of Manufacturing Management, Second Edition, 2001, Irwin McGraw-Hill, pp. 179

[122] Hopp, Wallace, Spearman, Mark, Factory Physics: Foundations of Manufacturing Management, Second Edition, 2001, Irwin McGraw-Hill Ibid., pp. 179

[123] Hopp, Wallace, Spearman, Mark, Factory Physics: Foundations of Manufacturing Management, Second Edition, 2001, Irwin McGraw-Hill Ibid., pp. 179

fundamental level why there is a connection between many of the lean practices and manufacturing performance.

2.4.3 Theory of Constraints

TOC was first popularized by its developer Eliyahu Goldratt, in his 1984 manufacturing classic, The Goal. Goldratt used a novel format to embed thoughtful and, at that time, a rather unique perspective about dealing with manufacturing problems and principles which lead to enhanced performance. The story line featured a struggling plant manager, relying upon interactions with a former professor turned manufacturing guru, in order to save his plant from bankruptcy. This book focused extensively on the strategic importance of the bottleneck and the conflict between traditional cost accounting and the actual goal of the company. This work presented a set of holistic measures to describe the impact of changes on overall performance. These measures were defined as follows.[124]

- Throughput – rate at which the firm produces money through sales.
- Inventory – things that the firm buys which are planned to be translated into throughput.
- Operating Expenses – costs incurred by the firm in translating inventory into throughput.

Also Goldratt developed the five focusing steps which he claims are essential for continuous improvement to occur.[125] Since these five focusing steps lie at the heart of improved performance within the TOC perspective, a brief explanation is provided below.

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124 Cox, James F. and Spencer, Michael S., The Constraints Management Handbook, 1998, CRC Press, Boca Raton, FL., pp. 56.

125 Goldratt, E.M., Cox, J., The Goal, 1984, Revised Edition, North River Press, Croton-on-Hudson, NY., pp. 307.

1. Identify the constraint – Using process mapping and basic routing data, the manager or engineer should be able to identify the bottleneck operation. Often simply finding the operation which has the largest build-up of WIP waiting to be processed is a good initial indicator. The constraint or the bottleneck is strategic since the slowest station governs the production rate of the entire line.
2. Exploit the Constraint – This step forces management to consider the strategic importance of the constraint and make modifications and policy changes which improve the performance of the constraint and thus the system. Practically this might mean implementing effective preventive maintenance program to improve its uptime. It also might mean adjusting manpower so that the constraint is run through breaks, which automatically improve the system capacity.
3. Subordinate All Else to the Constraint – This step recognizes that maximizing overall performance is not the result of optimizing the performance of each individual work center. In order to maximize production from the constraint, the efficiency of other work centers might need to be sacrificed.
4. Elevate the Constraint – find alternative sources to off load the constraining operation.
5. If the Constraint is Broken, go back to step 1: The caution is to not let inertia set in so that the new constraint is managed according to its strategic value. Often companies will continue to manage to the needs of the old constraint and not realize a different practice or policy should now be deployed in order to take advantage of the new constraint.

TOC's solution to the problem of production planning and control is called Drum-Buffer-Rope (DBR). The "drum" refers to the rate of production at the constraint or bottleneck. The bottleneck rate determines the production rate of the entire system. Therefore, plant management should attempt to place strategic "buffers" both before and after the constraint so that it is never blocked or starved. The buffer before the bottleneck is an inventory buffer, which is present in order to ensure that disruption in upstream processes do not cause starvation at the bottleneck. The buffer after the bottleneck is called a "space" buffer and its purpose is to prevent the blocking due to delays in downstream processes. A limit is placed on the constraint buffer, in order to ensure that excess inventory is not consumed and a minimum point is set, in order to ensure the system is not starved. The "rope" refers to the release of orders to the system based on the status of the buffer at the constraint. A trigger point is established based on the level of inventory at the constraint, which signals the release of an order to the plant floor. In setting the "trigger point" consideration should be given to the flow time of the order so that it reaches the constraint before the constraint's buffer goes below minimum.[126]

In later writings Goldratt, focuses on development of what is termed, the "Thinking Process" (TP). It is a logical structured approach to solving problems at their root cause by developing powerful solutions that enhance performance. Goldratt claims that DBR is the result of the application of the TP to problems of manufacturing. Other generic solutions were published that focused on other aspects of the business, these include project management, performance measurements, distribution, and sales & marketing.

A brief overview of the Thinking Process (TP) will be reviewed because of its possible relevancy to the development of the assessment methodology. The TP does not make any assumptions regarding a particular production systems theory. It is a purely logical diagramming approach that rigorously describes effect-cause-effect relationships (or trees) and attempts to develop breakthrough solutions (i.e., evaporating clouds) by careful articulation of the

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[126] Goldratt, E.M., Fox, R.E., The Race, Croton-on-Hudson, NY: North River Press, 1986., pp. 14.

fundamental conflict that gives rise to the core problem. There are several types of logical diagrams used in TP. The most common are summarized below.

- The Current Reality Tree (CRT) begins with identifying the undesirable effects (i.e., UDE's) that the current system exhibits and working backward to identify the root cause(s). "The CRT tells us *what to change* – the one simplest change to make that will have the greatest positive impact on our system." [127]

- The purpose of the Evaporating Cloud is to "resolve hidden conflicts" that underlie persistent problems.[128] The evaporating cloud assumes that an underlying conflict prevents the direct solution of the problem. This tool helps to begin to answer the question – *what to change to?*

- The Future Reality Tree (FRT) serves two purposes. First, it helps us verify that the proposed solution will produce the desired results. Second, it allows us to identify any unintended and unfavorable consequences, and can develop countermeasures to prevent their formation.

- The Pre-requisite Tree (PRT) identifies the implementation obstacles and guides us to identifying the best ways to overcome these obstacles. The outcome is the identification of project milestones and the sequence.

- The Transition Tree (TT) allows us to develop a detailed list of in-sequence instructions for implementing our solution.

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127 Dettmer, W.H. "Goldratt's Theory of Constraints: A Systems Approach to Continuous Improvement", ASQC Quality Press, Milwaukee, Wisconsin, 1997., pp. 23.

128 Ibid.

Finally the trees are validated through the use of "Categories of Legitimate Reservation" (CLR). "Essentially, they are eight rules, or tests of logic that govern the construction and review of the trees. To be logically sound a tree must be able to pass all of these tests."[129] There are eight elements to CLR and listed below.[130]

- Clarity – always the first reservation, focus is on proper communication.
- Entity Existence – "an entity is a complete idea expressed as a statement." Common problems include incomplete idea, not a single idea, statement validity.
- Causality Existence – reservations about whether or not the stated cause actually leads to the effect.
- Cause Sufficiency – this is the most common problem and reflects the case where the cause stated may influence the effect, but requires the existence of other causes in order to produce the effect.
- Additional Cause – this is the case where the stated cause is one source that leads to the effect but other independent causes also exist which lead to the same effect.
- Cause-Effect Reversal – This reflects the confusion where the cause is actually the effect, and the effect is actually the cause.
- Predicted Effect Existence – This means that if the cause and effect relationship is valid then another unstated effect might also result.
- Tautology – This refers to circular logic, which is where the effect is offered as a reason for the cause.

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[129] Ibid., pp. 26

[130] Ibid., pp. 34-54

2.5 Assessments & Audits

Manufacturing assessments have been used extensively by consulting firms as a primary means of selling services. NIST's network of MEP centers around the country frequently rely upon plant assessments as a means of determining the needs of the manufacturing firm so that subsequent revenue generating projects can be defined. Also, the subject of assessments has received a considerable amount of attention in the general business literature, particularly with the introduction of quality system registration (e.g., ISO 9000, QS 9000, …) and the Malcolm Baldridge National Quality Award (MBNQA) during the early part of the 1990's. However, the scholarly literature has not generally dealt directly with the subject of manufacturing enterprise assessments. A limited number of publications were found that dealt with the related subjects of self-assessments and audits.

Of particular interest to the research objective was the published work involving MBNQA, the Shingo Prize, and the Lean Enterprise Self Assessment (LESAT). Due to these publications exceptionally close relationship to the problem of developing a new taxonomy based assessment methodology, these approaches are discussed in greater detail within chapter three.

Publications were found dealing with the subject of self assessment, which is closely related to the objective of this research. Of particular interest were the comments of Ritchie and Dale (2000) "It is noticeable when sifting through the various publications based upon self-assessment that there is a lack of assistance provided in directing an organization toward a specific approach. Perhaps this is because there is more revenue to be gained by management consultancies if they only provide general comments on an approach, knowing that, if a company is committed to start self-assessment, they will want to do it correctly and will seek help. It could also be seen as an oversight of the quality management researchers in not giving this the attention that it deserves."[131] This very closely mirrors part of the motivation for this research project, which was the use of assessments to feed self serving tendencies among private consulting firms.

Self assessments have been defined as "holistic evaluation of organizational processes and performance using relatively little outside assistance."[132] There is a growing interest in this type of assessment.[133] The work by Ritchie and Dale 2000 focuses on the way 10 companies utilize self-assessment relative to criteria derived from a business excellence model (e.g., MBNQA and European Foundation for Quality). This work explores the organization's approach to self assessment, size of the company, use of external resources, and length of self-assessment (typically varied from 1-9 months). One of the key measures of success of the self assessment practice was whether or not the results are integrated into the business plan. The authors identified numerous approaches, which were classified into three basic categories: award based approaches, questionnaires, and workshops. Interestingly the study also identified some of the difficulties these firms experienced in practicing self-assessments. These included the following.

- Lack of commitment
- Process was too time consuming
- Maintaining the skills of the assessors

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[131] Ritchie, L., Dale, B.G., "An Analysis of Self-Assessment practices Using the Business Excellence Model", Proceedings of the Institution of Mechanical Engineers, 2000, pg. 600.

[132] Ford, M. W., Evans, J. R., Matthews, C. H., "Linking Self Assessment to the External Environment: An Exploratory Study", International Journal of Operations & Production Management, Vol. 24, No. 11, 2004, pg. 1175

[133] Ford, M. W., Evans, J. R., Matthews, C. H., "Linking Self Assessment to the External Environment: An Exploratory Study", International Journal of Operations & Production Management, Vol. 24, No. 11, 2004, pg. 1175

- Another key finding was that these companies often have undergone several self-assessments and the trend is to gradually reflect a more thorough model of TQM as they evolved. Some of the benefits this study observed as follows.
- The self assessment provided managers with a planning tool, to determine where they are, where they want to be, and how to get there.
- Some viewed the self assessment as a marketing tool and therefore reported a primary benefit in raising the public profile of the firm.

Ford et. al. (2004) performed an investigation of the self assessment motivators which are external to the organization. This work concluded that the following factors relate the practice of self-assessment to external influences.

- Availability of externally developed model (e.g., ISO 9000, MBNQA).
- Presence of boundary spanning individuals.
- Affiliation with professional and trade groups.
- Pressure from external entities (e.g., customers, corporate office).
- Potential for external reward and recognition.

They conclude "As a consequence of our findings, we are prone to consider the 'self' in self assessment a bit of a misnomer ... organizations often appear to rely substantially on outsiders to facilitate self-assessment."[134] This is related to the concern of this research which involves an external assessment team, using a defined methodology as the preferred means of conducting prescription driven assessments.

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[134] Ford, M. W., Evans, J. R., Matthews, C. H., "Linking Self Assessment to the External Environment: An Exploratory Study", International Journal of Operations & Production Management, Vol. 24, No. 11, 2004, pg. 1184

In addition, isolated publications were found on the use of manufacturing audits in support of the development of an effective manufacturing strategy. The work of Fine and Hax (1985) provide an audit based case study of a wire and cable manufacturer. This work focused on the use of the audit in terms of how the manufacturing strategy was deployed within the company. This work assessed strengths and weaknesses of current policies in the following manufacturing categories: facilities, capacities, vertical integration, process technologies, scope new products, human resources, quality management, manufacturing infrastructure, and vendor relations. Also the work of Platts and Gregory (1990, 1992) provided the methodology for the audit. They begin with the identification of manufacturing objectives, measures of current manufacturing performance, determination of the effects of current practices, and identification of the required changes. Menda (2004) published a case study of a pharmaceutical manufacturer which illustrates the use of an audit approach in the designing an organization's operations strategy. Menda states that this type of evaluation "requires the use of tested and usable tools for systematically examining those strategic decision areas and designing an operations system that supports the unique demands of the business."[135]

[135] Menda, R., "The Role of a Manufacturing Audit in crafting the Production System", International Journal of Operations and Production Management, Vol. 24, No. 9, 2004, pp. 929

CHAPTER 3

DEVELOPMENT OF ASSESSMENT METHODOLOGY

The objective of this chapter is to show the development of the Taxonomy Based Assessment Methodology (TBAM) and to explain its major components. The chapter begins with a review of published assessments which are of particular relevance to the development of TBAM. The two taxonomies upon which the methodology is built are next developed and discussed. The Manufacturing Enterprise Taxonomy (MET) is illustrated, in detail, through its use as an on-site survey instrument. The Production System Taxonomy is defined and discussed in terms of its use as a guideline for formulating recommendations. Finally, the overall TBAM approach is presented in terms of the evaluation-diagnosis-prescription framework and detail steps which form the basis of the methodology.

3.1 Review of Published Assessments

Over the last several years, manufacturing managers have frequently relied upon the use of assessments.[136] Assessment methods have been used by managers in a variety of ways, everything from the review of IT applications for suspected Y2K bugs to determining the shop floor's conformance to housekeeping standards.

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[136] Ritchie, L., Dale, B.G., "An Analysis of Self-Assessment practices Using the Business Excellence Model", Proceedings of the Institution of Mechanical Engineers, 2000, pp. 593

Assessment variety has been clearly noted in the literature by Ford, Evans, et. al. (2004) and by Ritchie and Dale (2000). In some cases, assessments are focused on specialized areas (e.g., health and safety, ISO 14001 Environmental Management System), while others consider broader enterprise-wide issues (e.g., ISO 9000 Quality Management System). External resources are occasionally used to perform assessments, while in other cases, primarily internal resources are used (i.e., self assessment).[137] Recently much focus has been placed on assessments whose purpose is to evaluate a firm's standing relative to a set of performance criteria (e.g., Malcolm Baldridge National Quality Award, European Foundation for Quality Management). Also a variety of assessment instruments have been found which evaluate the firm's level of maturity with respect to implementing principles of lean manufacturing (e.g., Shingo Prize, MIT's Lean Self Assessment Tool, and numerous MEP survey instruments).

Perhaps the most common type of assessments is for determining conformity with respect to an international set of standards. For example, the ISO 9001 standard for Quality Management Systems defines the minimum practices a firm should have in place if they are to achieve ISO 9001 registration. Similarly, the ISO 14001 Environmental Management System standard assists companies in defining practices within their operations which are needed in order for the firm to effectively manage its impact on the environment. Assessments against these types of standards are typically multi-day evaluations conducted by an outside firm utilizing a formal auditing approach. The result of these assessments is a pass/fail determination regarding whether or not the firm's practices satisfy the standard's minimum requirements. These types of assessments are primarily focused on measuring compliance.

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[137] Ford, M.W., Evans, J.R., Matthews, C.H., "Linking Self-Assessment to the External Environment: An Exploratory Study", International Journal of Operations & Production Management, Vol. 24. No. 11, 2004, pp. 1175.

Some assessments, rather than simply measuring compliance, are more focused on competitiveness and performance issues. For example, both the Shingo Prize and MBNQA reflect current thinking regarding best practices and include results driven criteria. Their purposes, which include measuring conformance to known best practices, also include substantial reliance on ensuring continuous improvement of performance measures.

The business literature contains many different types of assessments; however, all are generally based on an *evaluation* of a firm's actual practice with respect to an external reference model.

While Ritchie and Dale (2000) classified self-assessment approaches (e.g., award based, questionnaires, and workshops), nothing was found in the literature concerning an overall classification of assessments. This research suggests assessments can be classified using the following attributes.

- Scope (functional, enterprise wide)
- Purpose (conformance to external reference model, performance based recommendations)
- Type of Facilitation (self administered, third party)
- Type of Outcome (compliance to standard, award competition)

Based upon a review of the manufacturing assessment literature, the following methodologies were selected for further review.

- Malcolm Baldridge National Quality Award (MBNQA)
- Shingo Prize
- MIT's Lean Self Assessment Tool (LESAT).

This selection was based upon the perceived relevancy to the research goal (i.e., development of a taxonomy based methodology for conducting assessments of manufacturing enterprises). Specifically, the relevancy judgment was based on the following reasons. First, these three published assessments are concerned with issues impacting enterprise-wide performance. In addition, each methodology is built upon a foundation or model which purports to represent a systems understanding of the enterprise. Finally, these contain a survey instrument which attempts to bring objectivity into the highly subjective assessment domain.

3.1.1 Malcolm Baldridge National Quality Award (MBNQA)

MBNQA is an annual competition in which participating firms compete relative to the award's Criteria for Performance Excellence. The purpose of the Baldridge is to promote "high performance management practices that lead to customer satisfaction and business results."[138] MBNQA examiners review each application and conduct on-site assessments as required by the examination process. The firm which receives the highest score receives the prestigious Baldridge Award (an award may be given annually to a deserving firm within a variety of business types - manufacturing, service, small business, etc.).

MBNQA's Criteria for Performance Excellence (CPE) was developed to assist organizations to increase stakeholder and customer value. The CPE is built around an interrelated set of concepts and core values; which are, it is argued, embedded within high performing organizations. These include such attributes as visionary leadership, customer driven excellence, organizational learning, agility, management by fact, and systems perspective. These attributes

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[138] Evans, James, R. Dean, James W., Total Quality : Management Organization and Strategy, South Western College Publishing, Second Edition, 2000, pp. 68.

are embodied in the categories found within the CPE (see Figure 3.1 and 3.2).[139] As can be observed from Figure 3.1 MBNQA places great emphasis on business results, evidenced by 450 points of the total available 1,000 points (Figure 3.1).The rest of the points are distributed among the other remaining six categories (i.e., Leadership, Strategic Planning, Customer and Market Focus, Measurement, Human Resources, and Process Management). Characteristics of MBNQA's Criteria for Performance Excellence (CPE)[140] which are embedded within the previously mentioned categories are as follows.

1. Focus on results – composite measures are used to ensure that strategies are balanced. Outcome measures are required in the following areas: product, customer, financial and market, human resources, internal operational measures, leadership and social responsibilities.

2. Non-prescriptive and adaptive – focus is on results and not procedures, tools, and organizational structure. Also supports innovation and diversity in accomplishing requirements.

3. Support a *systems perspective* for achieving organization-wide goal alignment – action oriented cycles of learning via feedback between processes and results.

4. Support goal based diagnosis – the CPE constitute a set of 19 performance-oriented requirements. The CPE scoring includes both process and results dimensions. In this

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[139] 2006 Criteria for Performance Excellence, **http://www.baldridge.nist.gov/Business_Criteria.htm**, National Institute of Standards and Technology, Technology Administration, Department of Commerce. pp. 5.

[140] 2006 Criteria for Performance Excellence, **http://www.baldridge.nist.gov/Business_Criteria.htm**, National Institute of Standards and Technology, Technology Administration, Department of Commerce. pp. 7.

way, the CPE provides feedback on improvement opportunities relative to the 19 requirements.

I. Leadership (120)	*II. Strategic Planning (85)*	*III. Customer & Market Focus (85)*	*IV. Measurement, Analysis, & Knowledge Management (90)*
1.1 Senior Leadership (70) 1.2 Governance & social responsibilities (50)	2.1 Strategy Development (40) 2.2 Strategy Deployment (45)	3.1 Customer & Market Knowledge 3.2 Customer Relationships & Satisfaction	4.1 Measurement, Analysis, & Review of Org. Performance (45) 4.2 Information & knowledge Management (45)

V. Human Resource Focus (85)	*VI. Process Management (85)*	*VII. Results (450)*
5.1 Work Systems (35) 5.2 Employee learning & Motivation (25) 5.3 Employee Well-Being & Satisfaction (25)	6.1 Value Creation Process (45) 6.2 Support Processes & Operational Planning (40)	7.1 Product & Service Outcomes (100) 7.2 Customer Focused Outcomes (70) 7.3 Financial & Market Outcomes (70) 7.4 HR Outcomes (70) 7.5 Org. Effectiveness Outcomes (70) 7.6 Leadership & Social Responsibility Outcomes (70)

Figure 3.1 MBNQA's Criteria for Performance Excellence

While the MBNQA is primarily an external review of an enterprise, its guidelines can also be used as a basis for conducting self assessments. These self assessments (i.e., self analysis worksheet) may be used for strictly internal reasons or to prepare the site for the application process. This worksheet provides an opportunity for the firm to identify high importance areas within each of the seven CPE Categories. This enables the development of a goal oriented action plan developed by the applicant. The "process" focused Categories 1-6 have a common anchor. The results oriented categories have a separate scoring guideline. Some companies have found this useful to guide their internal continuous improvement efforts through using this as a basis for self assessment. The general systems model of the MBNQA scoring criteria is presented in Figure 3.2. Each category is not viewed as an independent entity, but comprises a total system that is assessed. Figure 3.2 shows the interrelationship of the award categories, based on information provided in the published award guidelines.

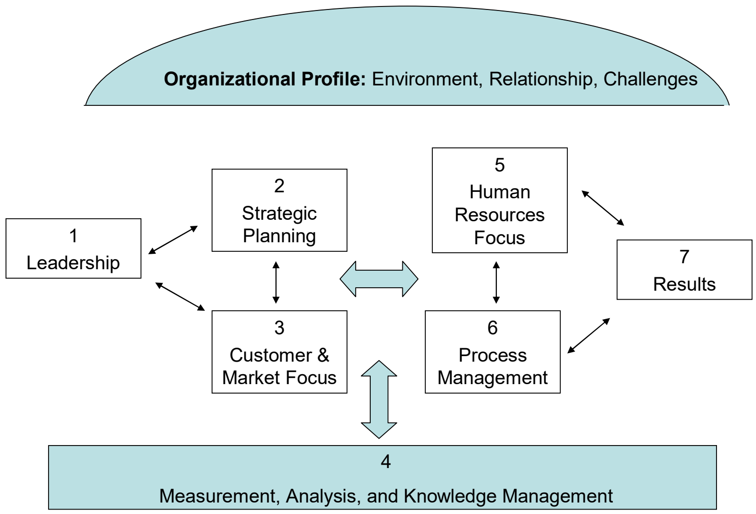

Figure 3.2 MBNQA Model

3.1.2 Shingo Prize

Similarly, the Shingo Prize is awarded annually to those manufacturing firms which exhibit high levels of maturity in lean manufacturing practices and accompanying results. In fact, the Shingo Prize has been referred to as the Nobel Prize of manufacturing.[141] The examination process works similar to the MBNQA, but with greater emphasis placed on the presence of specific lean practices. While differences exist between the MBNQA and the Shingo Prize, both

[141] Shingo Prize for Excellence in Manufacturing, Business Prize Applications Guideline 2005, **http://www.shingoprize.org/AwardInfo/BusPrize/BusinessGuidelines.pdf**, Utah State University, College of Business, pg. 8.

focus on the need to reward high levels of practice and performance from an overall systems perspective.

The Business Prize Guidelines are built around the Shingo Model, which reflects a *systems view* of the requirements to achieve world class results. The model consists of 11 elements, which are grouped into five categories (see Figure 3.3). Each of the key elements is weighted with a point value, which reflects the relative weight of each element. For each of these elements, the model emphasizes the elimination of waste, focus on high value activities, integrated and cooperative resources, critical process goals, and use of appropriate measurements. The five categories and their relative weights are found in Figure 3.3.

Enablers	Core Operations	Results	Business Results
I. Leadership Culture & Infrastructure (150)	***II. Manufacturing Strategies and System Integration (450)***	***IV. Quality, Costs, & Delivery (225)***	***V. Customer Satisfaction & Profitability (75)***
A. Leadership (75) B. Empowerment (75)	A. Manufacturing Vision and Strategy (50) B. Innovations in Market Service & Products (50) C. Partnering with Suppliers, Customers, & Environmental Practices (100) D. World Class Manufacturing Operations & Practices (50)	A. Quality and Quality Improvement (75) B. Cost & Productivity Improvement (75) C. Delivery & Service Improvement (75)	A. Customer Satisfaction B. Profitability
	III. Support Functions (100)		

Figure 3.3 Overview of the Shingo Prize

After the evaluation process is complete, companies are selected for recognition as either "recipients" or "finalists." There is no limit on the number of awards each year. As opposed to the MBNQA, the Shingo is not a competition between companies, but rather is based on assessed level of practice and performance against a common benchmark. Any firm that achieves this level of performance is considered a recipient.

3.1.3 Lean Enterprise Self Assessment Tool (LESAT)

Recently another assessment methodology has emerged from MIT's Lean Aerospace Initiative (LAI), termed the Lean Enterprise Self Assessment Tool (LESAT). An overview of LESAT elements is provided Table 3.1. LESAT focuses on the need to assess the level of maturity found within an organization in terms of its use of lean principles and practices to achieve enterprise value.[142] *LESAT assesses both an organization's leanness and its readiness to change.* The assessment involves an evaluation of numerous lean practices through its use of a Capability Maturity Model (CMM). The lean practices are defined by LAI's Lean Enterprise Model (LEM), which provides a taxonomy of lean principles and practices[143]. Defined within LEM is a set of 54 lean practices agreed upon by a panel of experts from industry, government, and academia. The determination of the firm's maturity in key lean practices assists in identifying gaps, strengths, and weaknesses and serves as input into the enterprise's strategic planning process. It is claimed that the LESAT instrument and the underlying theoretical models are based on the application of systems engineering concepts to the enterprise.[144]

The LESAT approach assumes that this set of lean practices, while not all inclusive, do constitute "important behaviors that lean organizations should exhibit."[145] The idea is that

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[142] Nightingale, Deborah, Mize, Joe, "Development of a Lean Enterprise Transformation Maturity Model", Information, Knowledge, Systems Management, 2002, IOS Press, Volume 3, pp 15-30.

[143] Nightingale, Deborah, Mize, Joe, "Development of a Lean Enterprise Transformation Maturity Model", Information, Knowledge, Systems Management, 2002, IOS Press, Volume 3, pp 16.

[144] Nightingale, Deborah, Rhodes, Donna, "Enterprise Systems Architecting: Emerging Art and Science within Engineering Systems", MIT Engineering Systems Symposium, March 2004, pp. 1

[145] Nightingale, Deborah, Mize, Joe, "Development of a Lean Enterprise Transformation Maturity Model", Information, Knowledge, Systems Management, 2002, IOS Press, Volume 3, pp 21.

assessing the firm's maturity against this set of "leading indicators" provides a snapshot of progress on the lean journey. The assumption is that conformance to these practices will ultimately result in the best value for the enterprise and its associated stakeholders.

Table 3.1

Overview of Lean Enterprise Self Assessment Tool (LESAT)

Lean Transformation / Leadership	Life-Cycle Processes	Enabling Infrastructure
Enterprise Strategic Planning 1. Integration of lean in planning 2. Focus on customer value 3. Leveraging the extended enterprise	***Business Acquisition and Program Management*** 1. Leverage lean capability for Business Growth 2. Optimize capability and Utilization of Assets 3. Provide ability to manage risk, cost, schedule, & perf. 4. Allocate resources for program development efforts	***Lean Organization Enablers*** 1. Financial system supports lean transformation 2. Stakeholders pull required financial info. 3. Promulgate the learning organization 4. Enable the firm with info, systems & tools. 5. Integration of environment, health, & safety
Adopt Lean Paradigm 1. Learning in lean for leadership 2. Senior management commitment 3. Lean vision 4. Sense of Urgency	***Requirements Definition*** 1. Establish req'mt definition process to optimize lifecycle value 2. Use data from ext. enterprise: optimize new req'mt definitions	***Lean Process Enablers*** 1. Process standardization 2. Common tools and systems 3. Variation Reduction
Focus on the Value Stream 1. Understanding the current value stream 2. Enterprise flow 3. Designing future value streams 4. Performance measure	***Develop Product & Process*** 1. Bring customer value into design: products & processes 2. Bring downstream stakeholder value: products & processes 3. Integrate process and product development	
Develop Lean Structure & Behavior 1. Organizational Orientation 2. Relationships based on trust 3. Open & timely communications 4. Employee empowerment 5. Incentive alignment 6. Innovation encouragement 7. Lean change agents	***Manage Supply Chain*** 1. Define & develop supplier network 2. Optimize network performance 3. Foster innovation and knowledge sharing throughout the supplier network	
Create & Refine Transformation Plan 1. Enterprise Level transformation plan 2. Commit resources for lean improvements 3. Provide education & training	***Produce Product*** 1. Use prod. knowledge and capability: competitive advantage 2. Establish and maintain a lean production system	
Implement Lean Initiatives 1. Develop detailed plans based on firm's plans 2. Tracking detailed implementation	***Distribute and Service Product*** 1. Align sales and marketing to production 2. Distribute product in lean fashion 3. Enhance value of delivered products & services 4. Give post delivery: service, support, & sustainability	
Focus on Continuous Improvement 1. Structured CI process 2. Monitoring lean progress 3. Nurturing the Process 4. Capturing lessons learned 5. Impacting Enterprise Strategic Planning		

3.1.4 Comparison of Major Assessment Methodologies

The key elements within each of the reviewed assessment methodologies are shown in the Figure 3.4. From a cursory review of these elements, the MBNQA and the Shingo Prize have the most in common. This is not surprising considering that the Shingo Prize program was developed after the MBNQA was established and in wide use. The LESAT methodology differs from the other two in that it was based on a "systems engineering" approach to the problem of assessing where a company is on its lean journey. However, when LESAT's 54 lean practices are considered, there appears to be a higher degree of commonality between LESAT and the other two approaches.

MDNQA	Shingo	LESAT
Leadership Senior leadership Governance & Social Responsibility **Strategic Planning** Strategy Development Strategy Deployment **Customer & Market Focus** Customer & Market Knowledge Customer Relationships & Satisfaction **Measurement, Analysis, & Knowledge Management** Measurement, Analysis, & Review of Org. Performance Information & Knowledge Management **Human Resource Focus** Work Systems Employee Learning & Motivation Employee Well Being & Satisfaction **Process Management** Value Creation Process Support Processes & Operational Planning **Results** Product & Service Customer Financial & Market HR Org. Effectiveness Leadership & Social Responsibilities	**Leadership Culture & Infrastructure** Leadership Empowerment **Manufacturing Strategies & System Integration** Manufacturing Vision & Strategy Innovations in Market Service & Products Partnering with Suppliers, Customers, & Environmental Practices World Class Manufacturing Operations & Practices **Support Functions** **Quality, Costs, & Delivery** Quality & Quality Improvement Cost & Productivity Improvement Delivery & Service Improvement **Customer Satisfaction & Profitability** Customer Satisfaction Profitability	**Lean Transformation/Leadership** Adopt Lean Paradigm Focus on the Value Stream Develop Lean Structure & Behavior Create & Refine Transformation Plan Implement Lean Initiatives Focus on Continuous Improvement **Life-Cycle Processes** Business Acquisition & Program Management Requirements Definition Develop Product & Process Manage Supply Chain Produce Product Distribute & Service Product **Enabling Infrastructure** Lean Organization Enablers Lean Process Enablers

Figure 3.4 Overview of Assessment Criteria

The purposes of the Shingo Prize and the MBNQA are similar. They were both established to *promote* the best management practices and to encourage firms to achieve world class results. The annual awards are announced with fanfare in order to bring as much publicity as possible. On the other hand, the purpose underlying the LESAT approach is for internal use as a management tool to assist companies in their lean transformation. It has not received the same level of public recognition as the MBNQA or the Shingo Prize.

All three approaches rely upon an anchored scoring approach to guide the appraisal process. MBNQA and Shingo rely upon external examiners to conduct the assessment; however, LESAT was developed for primary use within the firm using internal resources. MBNQA and Shingo both encourage the use of their criteria for self assessment in terms of preparing in advance for the examination process, while LESAT is completely focused on self-assessment. LESAT relies upon the Capability Maturity Model as a guide to scoring; while both MBNQA and Shingo use a generic anchoring approach, applicable across a broad range of criteria. The award based methods have specific concerns regarding reliability because they rely upon scores from a variety of examiners evaluating a variety of companies. LESAT scoring is principally concerned with scoring within the company and makes no attempt for the scores to be relevant externally.

The ultimate outcomes are different for each methodology. The MBNQA is used to recognize the "best" company within each of its award categories, the Shingo Prize recognizes all qualified firms based upon its benchmark of lean practices and results. LESAT's ultimate outcome is the identification of lean implementation and performance gaps so that appropriate feedback can be made to the firm's strategic plan. A comparison of each of these approaches can be found in Figure 3.5.

	Purpose	Approach	Outcome
MBNQA	National Award given to highest performing company in order to promote "high performance management practices that lead to customer satisfaction and business results"	Formal Application Anchored Scoring using external reference model: Criteria for Performance Excellence (7 Categories) Virtually no specific mandated. External Examination: written and on-site	One winner per category Secondary use is as a basis of self assessment in order to drive improvements
Shingo	Established to "promote awareness of lean manufacturing concepts and to recognize organizations that achieve world class manufacturing status"	Formal Application Anchored Scoring using the external reference model: Shingo Prize Model based on 11 Key Elements Suggested lean practices though none are mandated External Examination: written and on-site	Multiple winners based on exceeding "benchmark" Secondary use is as a basis for self assessment in order to drive improvements
LESAT	Developed to provide the company with a self assessment instrument that will enable them to identify lean maturity and readiness to change.	Internally Driven Need Anchored scoring, using Capability Maturity Matrix, based on "maturity" level across 54 specific lean practices derived from LEM Taxonomy Assumes relevant set of lean practices	Find gaps between current practice and desired across 54 LP's. Rolled up analysis within the 3 major lifecycles. Compare results between different areas and levels within the organization. Input into Strategic Planning process.

Figure 3.5 Comparison of Assessment Methodologies

3.1.5 Evaluation Based Methodologies

In many ways MBNQA, Shingo Prize, and LESAT are essentially *evaluation* based assessment methodologies. Their focus is on comparing or evaluating practices and results with respect to a set of criteria and/or system elements. While each methodology advocates the action plans for driving improvement, their published guidelines place little emphasis on generating rigorously defined recommendations. For example, see the following excerpts.

The Shingo Prize for Excellence in Manufacturing states "Additionally the application process itself serves as a vehicle for improvement. Applicants receive feedback, within the scope of the Achievement Report on *possible* improvements and suggestions for deployment."[146]

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[146] Shingo Prize for Excellence in Manufacturing, Business Prize Applications Guideline 2005, http://www.shingoprize.org/AwardInfo/BusPrize/BusinessGuidelines.pdf, Utah State University, College of Business, pg. 18.

The MBNQA's 2006 Criteria for Performance Excellence states the following "the feedback report helps organizations focus on their customers and improve organizational performance. Feedback is one of the most important parts of the Baldridge Award process; it provides a pathway for improvement."[147] The assessment provides a profile of strengths and improvement opportunities across 19 requirements based upon the scoring guidelines. "In this way assessments lead to actions that contribute to performance improvements in all areas …."[148]

In discussing the LESAT, Nightingale and Mize (2202) state the following. "The assessment process helped initiate healthy discussion and debate over the strengths, weaknesses, and opportunities across the enterprise. … In almost every case, the assessment process afforded the participants a more holistic understanding of the role of core, enabling, and leadership processes in delivering value across the entire value chain."[149]

Clearly each approach discusses the role of feedback, healthy discussion, and improved understanding. However, the problem of rigorous development of specific recommendations for improved performance, which is the primary concern of this research, is not addressed by these assessment methodologies.

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[147] 2006 Criteria for Performance Excellence, http://www.baldridge.nist.gov/Business_Criteria.htm, National Institute of Standards and Technology, Technology Administration, Department of Commerce. pg. 60.

[148] 2006 Criteria for Performance Excellence, http://www.baldridge.nist.gov/Business_Criteria.htm, National Institute of Standards and Technology, Technology Administration, Department of Commerce. pg. 7.

[149] Nightingale, Deborah, J., Mize, Joe H., "Development of a Lean Enterprise Transformation Maturity Model", Information, Knowledge, Systems Management, 2002, IOS Press, Volume 3, pp 27

3.2 Manufacturing Enterprise Taxonomy

The purpose of the manufacturing enterprise taxonomy (MET) is for use in characterizing particular manufacturing firms. Certainly, such a taxonomy can serve a variety of purposes. However, the purpose of this MET is to classify the current state of the firm in ways that are supportive of an overall assessment methodology. The ultimate use of this MET was to serve as the basis for the development of a on-site survey instrument, which can be completed within a two day time frame.

It is important to note that this MET is not intended to be an exhaustive scheme for classifying all attributes relevant to any particular manufacturing firm. In fact, an exhaustive classification is not practical and suited for use within the assessment approach. The research task was to select the specific attributes, which adequately characterize the firm and its current situation; yet the scope of the MET must be accomplishable within the required two day time frame. In view of the complexity of SMEs, this is a challenging task.

3.2.1 MET Development

This task was accomplished by identifying important variables and classification schemes from two primary sources. The first source was based upon a summary of published literature on important variables in terms of manufacturing performance. The second source was a synthesis of attributes drawn from other previously published assessment methodologies (i.e., MBNQA, Shingo, and LESAT). The resulting MET is one way, certainly not the only way, of synthesizing the data from these disparate sources. This research postulates that the MET developed herein is adequate for use within an overall assessment methodology. This assumption was tested using feedback obtained from case studies.

The MET used for this research was developed in several stages. The initial stage (version 1.0) was developed initially based on experience and exposure to the general business literature (see Figure 3.6). Next, the academic literature was carefully reviewed and summarized based on important classification variables and major themes drawn from conclusions and inferences within each published work reviewed. In addition, the structure and taxonomies of other published assessment methodologies (i.e., MBNQA, Shingo Prize, and LESAT) were investigated. All of these sources served as inputs for the development of the resulting version of the manufacturing enterprise taxonomy (version 2) which was used as input into the assessment methodology. The process is described generally in Figure 3.7.

1.0 Business Environment	
	1.1 Regulartory Environment
	1.2 Market Conditions
	1.3 Exernal Threats
	1.4 Seasonality
2.0 Product Characterization	
	2.1 Product Volume
	2.2 Product Complexity
	2.3 Product Variety
	2.4 Product Lifetime
3.0 Process Characterization	
	3.1 Process Integration
	3.2 Process Complexity
	3.3 Layout
	3.4 Capacity
4.0 Plant Operations	
	4.1 Plant Structure
	4.2 Major Process
	4.3 Bottleneck
	4.4 Quality System
5.0 Human Resources	
	5.1 Teaming Reliance
	5.2 Skill Level
	5.3 Employee Development
6.0 Enterprise Health	
	6.1 Working Capital
	6.2 Inventory Turns
	6.3 Debt Ratio
7.0 Continuous Improvement	
	7.1 Program Formality
	7.2 Effectiveness
8.0 Performance Measures	
	8.1 Operations
	8.2 Financial

Figure 3.6 Initial MET (version 1.0)

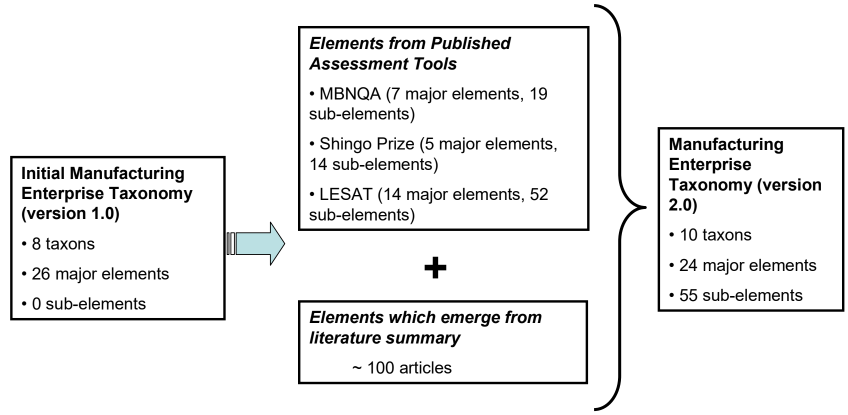

Figure 3.7 Development of the MET

The next section describes the development of the MET in more detail from the two major sources: published literature on manufacturing performance and other published assessments.

3.2.1.1 MET Source: Research on Manufacturing Performance

The purpose of this section is to illustrate common themes and general conclusions derived from the body of published research on manufacturing performance. Of course, chapter two provides a thorough review of the literature, but the objective of this section is to highlight and classify. These summaries are used, in part, to justify the full development of the MET, version 2.0. The subsequent tables (i.e., Tables 3.2, 3.3, 3.4, 3.5, 3.6, and 3.7) summarize the six major themes that emerge from the literature.

- Performance Measures
- Extended Enterprise
- Human Resources / Workforce Management

- Product / Process Characterization
- Relationship of Manufacturing to Enterprise Strategy
- Approach to Continuous Improvement

Table 3.2

Summary of Work on Performance Measures

Finding from Literature	References
Performance measures should be closely linked to strategy	Skinner (1969), Wheelwright (1978), Adam et. al. (1989)
Performance measures must include a balance of financial and non-financial measures. Traditional cost accounting measures are frequently not useful in driving improvements.	Ghalayini and Noble (1996), Kaplan (1984), Goldrat (1984)
General consensus regarding broad dimensions of performance measurements: cost, quality, customer responsiveness (flexibility, speed, and delivery).	White (1996), Gilgeous (2001)
Based upon an extensive literature review, the following performance measures are used in this study: cost, quality, speed, deliver, volume flexibility, design flexibility.	Ketokivi and Schroeder (2004)
Based upon a literature review, the following dimensions of manufacturing performance are used: cost reduction, customization, delivery speed, cycle-time reduction, quality conformance, time to introduce new products.	Das (2003)
One of the barriers to success for small manufacturers is the lack of access to operating capital and investment funds.	National Research Council, 1993
A wide range of performance improvement (cost, quality, speed, flexibility) are positively related to both pull production and process focus action programs.	Laugen et. al. (2005)

Table 3.3

Summary of Work on Extended Enterprise

Finding from Literature	References
Higher performing plants depend to a large degree upon better customer/supplier relationships and are not simply a result of internal practices. High performing plants tend to exist in high performing supply chains. Fluctuating schedules can be disruptive to production, but its effects are mitigated at lower inventory levels.	Lowe, et. al. (1997)
Infrastructure variables (including "supplier relationship") are sufficient to predict performance – without consideration given to specific quality management and JIT practices.	Flynn, et. al. (1997)
The forces of competition and demands of customers can drive firms to have more strategically effective manufacturing .	Gilgeous (2001)

Table 3.4

Summary of Work on Workforce Management / HR Practices

Finding from Literature	References
HR practices considered in isolation show little relationship to performance. High performing plants are present without a formal team structure and a large number of plants with teams are failing to perform. High performing Japanese plants tend to have highly structured teams.	Lowe et. al. (1997)
Infrastructure variables (including "workforce management" and "work attitudes") are sufficient to predict performance – without consideration given to specific quality management and JIT practices.	Flynn, et. al. (1997)
Suggests that firm's that focus on specific JIT practices do not perform as well as those that work on developing the overall infrastructure (i.e., strategy, quality management, and workforce management).	Sakakibara et. al. (1997)
HR practices are subordinate to lean. Some evidence that decentralized decision making and operator cross training are significantly related to performance. Plants which combine lean initiatives and work organization structures (i.e., teams and decentralized decision making) have greater impacts resulting from investment in advanced manufacturing technologies.	Das et. al. (2003)
Lean practices (i.e., work teams, job rotation, improved product development efforts, …) all play a role in helping plant's successively absorb complexity.	MacDuffie et. al. 1996
Cross functional cooperation and long term supplier relationships are related to increased levels of conformance quality as was the use of SPC, but only if the firm placed a high level of importance on improving quality	Ketokivi and Schroeder (2004)
"Cross training the employees is related to faster delivery performance, but only if the plant is trying to implement a fast delivery strategy	Ketokivi and Schroeder (2004)
Cross training of operators and JIT practices both are related to achieving gains in lowering cost	Ketokivi and Schroeder (2004)
Cross functional cooperation is associated with conformance quality.	Ketokivi and Schroeder (2004)

Table 3.5

Summary of Work on Product & Process Characterization

Finding from Literature	References
The effect of automation depends upon the type of plant. Fluctuating schedules can be disruptive to production, but its effects are mitigated at lower inventory levels.	Lowe et. al. (1997)
JIT is related to the performance areas of fast deliveries, low cost, and low cycle times.	Ketokivi and Schroeder (2004)
Both coupling "hardside technologies" (e.g., CADCAM, CNC) and "softside technologies" (e.g., JIT, TQM) produces significant improvements in non-financial manufacturing performance. There is not a single set of technologies that benefit all manufacturers. Several technologies need to be matched simultaneously for investment.	Henderson et. al. (2004)
Persistent negative effect of part complexity on productivity. Lean practices (i.e., work teams, job rotation, improved product development efforts, …) all play a role in helping plant's successively absorb complexity.	MacDuffie et. al. 1996
Several contingency variables are found to be significant, which mediates the effect of investment in advanced manufacturing technologies. The greatest impact is lean practices (particularly JIT supply, SMED, and Kanban). HR practices are subordinate to lean. The effect of CAD is negative across levels of the contingency variables. Possibly relating to overly complex products. Plants which combine lean initiatives and work organization structures (i.e., teams and decentralized decision making) have greater impacts resulting from investment in advanced manufacturing technologies.	Das et. al. (2003)
Cross functional cooperation is significant in terms of achieving design flexibility, but only in the presence of a strategic commitment to design flexibility	Ketokivi and Schroeder (2004)
The argument here is that companies can invest in process improvements and other organizational capabilities that shift the trade-off point between cost and product variety considerably.	MacDuffie et. al. (1996)
Design for manufacturability is primarily associated with fast delivery and low cycle times.	Ketokivi and Schroeder (2004)
A wide range of performance improvement (cost, quality, speed, flexibility) are positively related to both pull production and process focus action programs.	Laugen et. al. (2005)

Table 3.6

Summary of Work on Relationship of Manufacturing to Enterprise Strategy

Finding from Literature	References
Suggests that firm's that focus on specific JIT practices do not perform as well as those that work on developing the overall infrastructure (i.e., strategy, quality management, and workforce management).	**Sakakibara et. al. (1997)**
The forces of competition and demands of customers can drive firms to have more strategically effective manufacturing (as indicated by the presence of 22 different manufacturing improvement programs). "Strategic manufacturing effectiveness" is supported by "manufacturing pro-activeness" and "an emphasis on formulating manufacturing strategy." Strategic manufacturing effectiveness is related to "manufacturing competence."	Gilgeous (2001)
Failure for the firm to decide which of Porter's generic strategies (cost leadership, differentiation, and focus) to employ will result in the firm attempting to compete on all dimensions simultaneously – leading to a weakened competitive position.	Porter (1985).
Porter's strategy taxonomy was found to be supported (degree of market differentiation and market scope) Structure supporting the manufacturing task is multidimensional: combinations of capabilities is more important than the possession of individual capabilities. Three distinct types of manufacturers were found in terms of strategy: Caretakers, "Marketeers", and Innovators.	Miller and Roth (1994)
Only one practice (JIT) is related to more than two dimensions of competitive performance. This implies that as far as competitive performance is concerned, practices must be implemented for the right reasons	Ketokivi and Schroeder (2004)
Indications are that high performing enterprises must compete on multiple priorities simultaneously. A critical aspect of the process of developing operations priorities is discerning the types of manufacturing improvement programs and initiatives that will match objectives.	Sum et. al. (2004),
"We conclude that manufacturing operations and practices are indeed strategic, that they are few best practices in the sense that they contribute to the competitive manufacturing performance in multiple dimensions." … "Incorporating strategic priorities into the analysis has provided us with a better understanding of the practice-performance relationships. *The evidence shows that some practices are better suited to some strategies than to others.*"	Ketokivi and Schroeder (2004)
Strong relationship between the effect of SPC on conformance quality, but only in those plant's that place a high priority on quality.	Ketokivi and Schroeder (2004)

Table 3.7

Summary of Work on Approach to Continuous Improvement

Finding from Literature	References
Investing in one program alone (e.g., zero defects) does not drive improvement in a dimension of performance like quality – it is rather the cumulative effect of multiple choices,.	Gilgeous (2001)
Best practices should be thought of as bundles – which were termed action programs. For example, Pull production" is an action program that includes practices like Kanban, SMED, …	Laugen et. al. (2005)
Best practices tend to be context specific. When investigating the applicability of a specific practice the type of industry, presence of supporting infrastructure practices in place, presence of other complimentary improvement practices should be considered.	Davies et. al. (2002)
Significant interaction effect between quality practices and JIT practices.	Flynn et. al. (1997)

Next these themes and summaries are consolidated and re-classified in a manner more closely related to the development of taxons (i.e., major classifications). This results in the following suggested taxons based strictly on the literature contribution (observed in Table 3.8).

- Leadership
- Strategic Planning and Deployment
- Customer / Market Focus
- Information System
- Human Resources
- Process Focus
- Process and Product Development
- Performance Measures
- Supplier / Distributor Relationships
- Approach to Continuous Improvement

Table 3.8

Taxons Based Strictly on the Published Literature

Taxons	***Supporting Evidence from the Literature***
Leadership	Sakakibara, et. al. 1997 infrastructure practices (strategy, quality management, and workforce management) rather than specific JIT practices most impacted performance. Flynn, et. al., 1997 infrastructure variables (management support, plant environment, supplier relationship) had greatest impact on performance (cycle-time, and quality).
Strategic Planning & Deployment	Morita & Flynn (1997) mfging strategy includes type of product, where produced, whom sold to. Miller & Roth's developed an empirical taxonomy of manufacturing strategies (caretakers, marketeers, innovators) - also market scope and differentiation were found to be significant - provides empirical evidence to Porter's generic strategies. Sum et. al. (2204) found similarly the following clusters in a survey of Singapore SMEs - all-arrounders, efficient innovators, differentiators. Kathuria (2000) found that different manufacturers use different strategies to compete in the same industry and yet still be equally effective. Morita & Flynn (1997) found that a significant "Strategic Focus" (strategy adoption, management practices, technology adoption) cluster in terms of describing the difference between high performing firms and others.
Customer/Market Focus	Lowe et. al., 1997 show that higher performing plants are able to respond more quickly to changes as requested by their customer.
Information System	DAS 2003 references hardside Advanced Manufactuiring Technologies (CADCAM, CNC), also Henderson et. al. 2004 evaluated integrated manufacturing technolgies
Human Resources	Flynn 1997 concluded that infrastructure varaibles including workforce management practices had the greatest impact on performance. Simialrly, Sakakibara et. al., 1997 fund that "workforce management" among other factors most strongly related to performance.
Process Focus	Morita & Flynn (1997) found that a significant "Operations Management" (PC system, shop floor practices, defined production system) cluster in terms of describing the difference between high performing firms and others. Lowe, et. al. 1997 high performing plants exhibited a high degree of process control and discipline.
Process & Product Development	Laugen, et. al. (2005) provided some empirical evidence that new product development process belonged in the class of best practices. Morita & Flynn, 1997 show that speed of new product introduction is one of the differentiators between world class manufacturers and others. Keokivi, et. al., 2004 DFM impacted the fast delivery and low cycle time dimension of performance.
Performance Measures	Ghalayini, Kaplan, Goldratt consensus that measures are not strictly financial, but multi-dimensional (cost, quality, speed, flexibility), White (1996) taxonomy of 125 performance measures, Skinner (1969), Wheelwright (1978) performance measures linked to strategy. Morita & Flynn (1997) performance measures drive firm's continuous improvement efforts. Mapes (1997) Sand Cone Model - cost, quality, speed, dependability - acquired cummulatively.
Supplier/Distributor Relationships	Laugen, et. al. (2005) provided some empirical evidence that supplier strategy & outsourcing belonged in the class of best practices. Keokivi, et. al., 2004 supply chain relationships impacted certain dimensions of performance (low cost, and conformance quality).
Approach to Continuous Improvement	Laugen et. al., 2005 found that certain "bundle of practices" were more strongly related to performance than others. Flynn, Schroeder, et. al. 1997 showed that the effects of quality management and JIT practices on performance were most clearly seen as interactions.
Use of Specific World Class Practices	Davies & Kochhar (2002) - defined best practices, concluded context specific, need to be evaluated holistically (i.e., across all dimensions of performance). Laugen et. al. (2005) conclude the value of individual practices does not stand alone but depends upon others (i.e., re-enforcing). Overall best practices were process focus, pull, equipment productivity, & environmental cpability Flynn, Shroeder (1997) found significant ineraction betweeen quality & JIT practices. Morita & Flynn found high degree of a certain cluster of practices & all aspects of performance - also found contigency relationship exists between practices and defined the need to seperate immature and mature uses of a practice. Katokivi and Shoeder, 2004 showed that some practices are better suited to some strategies than others. MacDuffie et. al., 1996 lean practices enable firms to better handle product variety &
Product & Product Characterization	Hayes & Wheelwright (1979) product-process structure has ben used by many researchers - some empirical evidence has been found. Goldratt's VAT - logical product-process structure (Cox and Spencer, 1998). Mapes at. al., 1997 product variety is negatively correlated with various aspects of performance. Leachman et. al., 2005 found that R&D commitment and time compression during manufacturing are positively related to manufacturing performance
Automation	Lowe et al., 1997 the effect of automation depended upon plant type. Das et. al. 2003 the effect of advanced manufacturing technologies depends upon the leanness of the plant. Henderson, et. al. 2004, a single technology does not appear to benefit all, therefore matching several technologies simultaneously. Several studies (e.g., Das & Jayaram, 2003; Small, 1999, Henderson et. al. 2004) have looked at the connection of IT driven tools (CAE, CIM, FMS, CAD) and attempted to identify their relationship to manufacturing performance. The results are mixed and caught up in an interaction with softside issues like presence of teams and maturity in lean.

Table 3.9

Taxons Emerging from Other Published Assessment Methodologies

Taxons	***Assessment Methodologies***		
	LESAT	**Shingo**	**MBNQA**
Leadership	☑ Leadership in lean transformation (28 LPs)	☑ evalaution of leadership wrt to strategies & practices (150/1000 points)	☑ evaluation of how senior leaders set vision & values, drive goal seeking action, financial integrity, & social responsibility (120/1000)
Strategic Planning & Deployment	☑ included as one of the TTL processes (3 LPs)	☑ included under leadership includes statements of strategy, resource allocation, Manufacturing vision & strategies (50/1000)	☑ Evaluation of how strategy is developed, timing, use of SWOT, & deployment of actions (85/1000)
Customer/Market Focus	☑ focus on customer value, bring customer value into product/process design, (2 LPs)	☑ partnering with customers, measure of customer satisfaction, delivery performance, ...(~210/1000)	☑ customer & market focus, customer focused outcomes (185/1000)
Information System	☑ Lean Org. Enablers: Stakeholders pull required information, enable firm with info systems & tools (2 LPs)	MIS briefly mentioned along with other non-manufacturing support functions. Performance data frequently mentioned	☑ data availability, accuracy, integrity, timeliness (~45/1000)
Knowledge Management	☑ Under "Manage Supply Chain" - foster innovation & knowledge sharing, "focus on CI" - capturing lessons learned. (2 LPs)	"knowledge management system" listed under Leadership Culture & Infrastrucutre	☑ management of organizational knowledge, transfer to other employees, suppliers, customers (45/1000)
Human Resources	☑ Under "Develop Lean Structure" - all 7 LPs. "Create Transformation Plan - provide education & Training (8 LPs)	☑ Under "Leadership & Infrastructure" - empowerment, use of teams, suggestions systems, reward & recognition (75/1000)	☑ Human Resource Focus - org. promote teamwork, empoerment, learning & growth, employee well-being & satisfaction (85/1000)
Process Focus	☑ All 4 LP's under "Focus on the Value Stream, all 18 LPs undder "Life-Cycle Processes" (22 LPs)	☑ Inherent within the "WCM operations & Processes" section (250/1000)	☑ "Process Management" - key value creation processes identified & managed, as well as key support processes. (85/1000)
Regulatory Environment	not specifically mentioned	not specifically mentioned	Preface: Org. Profile, leadership wrt social responsibility, also in Social Outcomes
Competitve Environment	☑ under "Produce product" - mention of use of product knowledge to gain competitive advantantage (1 LP)	not specifically mentioned - though indirectly through references to WC practices.	Preface: Org. Profile, listed under Stratgic Planning
Process & Product Development	☑ "Requirements Definition" - 2 LPs, "Develop Product & processes" - 3 LPs (5 LPs)	☑ Innovations in Product Design, Development, ... (50/1000)	Mention is embedded within "Value Creation Process"
Performance Measures	☑ "Focus on the Value Stream" - performance measures & implied under several other elements. (1 LP)	☑ "Quality & Quality Improvement", Cost & "Producutivity Improvement", Delivery & Service Improvement" & "Business Outcomes" (300/1000)	☑ "Meas. Analysis & Review of Org Performance", all the Outcome Results elements - (450/1000)
Supplier/Distributor Relationships	☑ "Manage the Supply Chain" - (3 LPs)	☑ Mentioned under II C. "Parterning w/Suppliers & Customers" - including supplier satisfaction	Little mention - embedded comments within "Process Mangement"
Approach to Continuous Improvement	☑ Essentially evalauting the firm's maturity wrt a defined formal approach. Much emphasis on the "system"	☑ assessing for the presence of a very "Toyota like" production system.	☑ Assessing for the presence of a formal process for improving organizational excellence wrt to the CPE.
Financial	"Enabling Infrastructure" - lean enabler - financial system supports lean	Financial measures listed under "Outcome Results"	☑ mention under Leadership wrt to "ethical governance" also "Financial & Market Outcomes" (~35/1000)
Use of Specific World Class Practices	☑ Little mention of specifc tools - referenced in "Enabling Infrastructure" & LP - establish & maintain a lean production system (3 LP)	☑ Much emphasis throughout the crieria - particualrly in II D. WCM Ops & Processes	Virtually no mention of any specific WC practices
Product & Product Characterization			
Automation			

The next step was to review the three assessment methodologies without reference to the literature driven taxons. This allows the themes to be driven unfettered from the source of other published assessments. The results of this work are illustrated in Figure 3.8. The use of color coded text is used so that common threads can more easily be traced across the methodologies. This evaluation results in the following ten major themes or taxons driven from other published assessment methodologies. Also identified in parentheses are the associated methodologies that appear to strongly address each of the taxons.

- Leadership … (MBNQA, Shingo, LESAT)
- Strategy Planning … (MBNQA, Shingo, LESAT)
- Focus on Customers … (MBNQA, Shingo, LESAT)
- Performance Measures … (MBNQA, Shingo, LESAT)
- Process Focus … (MBNQA, Shingo, LESAT)
- IT / Knowledge Management … (MBNQA, Shingo)
- Empower Employees … (MBNQA, Shingo, LESAT)
- Integrated Product & Process … (Shingo, LESAT)
- Extended Enterprise … (Shingo, LESAT)
- Financial … (MBNQA, Shingo)

It is interesting to note that six out of the above ten taxons are clearly supported by all three methodologies. These were leadership, strategy planning, focus on customers, performance measures, process focus, and empower employees. Each of the remaining four taxons were clearly rooted in any two of the methodologies. Therefore, it appears as if these ten taxons adequately represent the published methodologies.

I. MBNQA	II. Shingo	III. LESAT	Major Themes
Organizational Profile Description Challenges (competitive) **Leadership** Senior leadership Governance & Social Responsibility **Strategic Planning** Strategy Development Strategy Deployment **Customer & Market Focus** Customer & Market Knowledge Customer Relationships & Satisfaction **Measurement, Analysis, & Knowledge Management** Measurement, Analysis, & Review of Org. Performance Information & Knowledge Management **Human Resource Focus** Work Systems Employee Learning & Motivation Employee Well Being & Satisfaction **Process Management** Value Creation Process Support Processes & Operational Planning **Results** Product & Service Customer Financial & Market HR Org. Effectiveness Leadership & Social Responsibilities	**Leadership Culture & Infrastructure** Leadership Empowerment **Manufacturing Strategies & System Integration** Manufacturing Vision & Strategy Innovations in Market Service & Products: • Concurrent engineering Partnering with Suppliers, Customers, & Environmental Practices World Class Manufacturing Operations & Practices **Support Functions** Alignment to support mfging: HR, IS, Acctg. … **Quality, Costs, & Delivery** Quality & Quality Improvement Cost & Productivity Improvement Delivery & Service Improvement **Customer Satisfaction & Profitability** Customer Satisfaction Profitability	**Lean Transformation/Leadership** Enterprise Strategic Planning: *lean in planning, Focus on customer value, leverage ext. enterprise* Adopt Lean Paradigm: *Execs to learn & commit , Sense of Urgency* Focus on the Value Stream: Current & Future, *Performance Measures* Develop Lean Structure & Behavior: *Org. Structure, Incentive alignment, Trust based, open communications, Innovations & change agent* Create & Refine Transformation Plan Implement Lean Initiatives • *Develop detailed plans & track implementation* Focus on Continuous Improvement: *Structured CI, Lessons learned, Impact on Strategic Plan* **Life-Cycle Processes** Business Acquisition & Program Mgm't • *leverage capability, allocate resources for program development* • *Provide capability to manage risk, schedule, & cost* Requirements Definition: life-cycle value Develop Product & Process: *customers into development, integrate product & process development* Manage Supply Chain: *supplier network, innovation & knowledge sharing in chain* Produce Product: *product knowledge & lean* Distribute & Service Product: *align sales, marketing, & mfging, enhance value* **Enabling Infrastructure** Lean Organization Enablers: *supported by financial systems, learning org., integration of environment, health, & safety.* Lean Process Enablers: *standardization, variation reduction*	Leadership (I, II, III) Strategy Planning (I, II, III) Focus on customers (I, II, III) Performance Measures (I, II, III) Process Focus (i.e., value chain) (I, II, III) IT/ Knowledge Management (I, II) Empower Employees (I, II, III) Integrated Product & Process (II, III) Extended Enterprise (II, III) Financial (I, II)

Figure 3.8 Major Themes from Published Assessments

3.2.1.2 Development of MET (version 2)

The following Figure summarizes the major taxons which emerged from the relatively independent sources: research literature on manufacturing performance and the other published methodologies. In addition, this figure presents the connection between these two sources and the MET (version 2) that was developed.

Development of Taxons for the MET

Major Themes From Published Assessments	***Major Themes from the Literature***	***MET (version 2.0)***
Leadership	Leadership	Business Environment
Strategy Planning	Strategy Planning & Deployment	Leadership
Focus on Customers	Customer Focus	Customer Market Focus
Performance Measures	Information Systems/CAD CAM	Information System & Knowledge Management
Process Focus (i.e., value chain)	Process Focus	Human Resources
IT/ Knowledge Management	Process & Product Development	Development of Products & Processes
Empower Employees	Performance Measures	Product & Process Characterization
Integrated Product & Process	Supplier/Distributor Relationships	Extended Enterprise
Extended Enterprise	Specific World Class Practices	Approach to Continuous Improvement
Financial	Product & Process Characterization	Enterprise Financial Health
	Automation	
	JIT/TQM	

Figure 3.9 Development of Taxons for the MET

The development of the entire MET (version 2) structure is illustrated in Figure 3.10.

MET (version 1.0)	MBNQA	Shingo	LESAT	Literature Consensus	MET (version 2.0)
1.0 Environment 1.1 Regulatory Environment 1.2 Market Conditions 1.3 External Threats 1.4 Seasonality **2.0 Product Characterization** 2.1 Volume 2.2 Complexity 2.3 Variety 2.4 Lifetime **3.0 Process Characterization** 3.1 Process Integration 3.2 Complexity 3.3 Layout 3.4 Capacity **4.0 Plant Operations** 4.1 Plant Structure 4.2 Major Process 4.3 Bottleneck 4.4 Quality System **5.0 Human Resources** 5.1 Teaming 5.2 Skill Level 5.3 Development **6.0 Financial Health** 6.1 Working Capital 6.2 Inventory Turns 6.3 Debt Ratio **7.0 Continuous Improvement** 7.1 Formality 7.2 Effectiveness **8.0 Performance Measures** 8.1 Operations 8.2 Financial	**Leadership** Senior leadership Governance & Social Responsibility **Strategic Planning** Strategy Development Strategy Deployment **Customer & Market Focus** Customer & Market Knowledge Customer Relationships & Satisfaction **Measurement, Analysis, & Knowledge Management** Measurement, Analysis, & Review of Org. Performance Information & Knowledge Management **Human Resource Focus** Work Systems Employee Learning & Motivation Employee Well Being & Satisfaction **Process Management** Value Creation Process Support Processes & Operational Planning **Results** Product & Service Customer Financial & Market HR Org. Effectiveness Leadership & Social Responsibilities	**Leadership Culture & Infrastructure** Leadership Empowerment **Manufacturing Strategies & System Integration** Manufacturing Vision & Strategy Innovations in Market Service & Products Partnering with Suppliers, Customers, & Environmental Practices World Class Manufacturing Operations & Practices **Support Functions** **Quality, Costs, & Delivery** Quality & Quality Improvement Cost & Productivity Improvement Delivery & Service Improvement **Customer Satisfaction & Profitability** Customer Satisfaction Profitability	**Lean Transformation/Leadership** Adopt Lean Paradigm Focus on the Value Stream Develop Lean Structure & Behavior Create & Refine Transformation Plan Implement Lean Initiatives Focus on Continuous Improvement **Life-Cycle Processes** Business Acquisition & Program Management Requirements Definition Develop Product & Process Manage Supply Chain Produce Product Distribute & Service Product **Enabling Infrastructure** Lean Organization Enablers Lean Process Enablers	Leadership Strategic Planning Customer/Market Focus Information system Knowledge Management Human Resources Process Focus Regulatory Environment Competitive Environment Process & Product Development Performance Measures Supplier/Distributor Relationships Approach to Continuous Improvement Financial Specific World Class Practices Product & Process Characterization Automation	**1.0 Business Environment** 1.1 Competitive Environment 1.2 Regulatory Environment 1.3 Market Conditions **2.0 Leadership** 2.1 Strategic Planning & Deployment 2.2 Culture of Empowerment **3.0 Customer Market Focus** 3.1 Translation of Requirements 3.2 Positioning **4.0 Information System** 4.1 Access to information 4.2 Supportive of Improvement Efforts **5.0 Human Resources** 5.1 Maturity in Teaming 5.2 Employee Skill Level **6.0 Development of Products & Processes** 6.1 Product Development 6.2 Process Development **7.0 Product & Process Characterization** 7.1 Product 7.2 Process 7.3 Product-Process **8.0 Extended Enterprise** 8.1 Supply Chain 8.2 Distribution Chain **9.0 Approach to Continuous Improvement** 9.1 Performance Measures 9.2 Process Focus 9.3 Use of Specific WC Practices 9.4 Quality System **10.0 Enterprise Financial Health** 10.1 Capital Availability 10.2 Profitability

Figure 3.10 Development of the MET (version 2.0)

1.0 Business Environment	Descriptive
2.0 Leadership	Prescriptive
3.0 Customer/Market Focus	Prescriptive
4.0 Information System & Knowledge Management	Presciptive
5.0 Human Resources	Prescriptive
6.0 Development of Products & Processes	Prescriptive
7.0 Product & Process Characterization	Descriptive
8.0 Management of Extended Enterprise	Prescriptive
9.0 Approach to Continuous Improvement	Prescriptive
10.0 Enterprise Financial Health	Descriptive

Figure 3.11 MET Summary

Each of these 10 major attributes (i.e., taxons) are broken down into two levels of detail. The second level contains 24 elements and the third level possesses 55 elements. Therefore the MET, at its most detailed level, characterizes the firm across 55 elements. See the Figure 3.12 for a complete breakdown of the MET.

In addition to element definition, rating guidelines are defined which anchor responses across the lowest level of the taxonomy. Based upon these ratings, the firm being surveyed is classified across the multiple dimensions of the MET.

Based upon the preceding discussion, the MET used within this research relies upon the ten major taxons upon which to classify manufacturing enterprises. In the development of this taxonomy, attention was paid to two types of taxons: descriptive and prescriptive (see Figure 3.11). The descriptive taxons are comprised of those attributes that describe the firm's "facts of life." This provides information either about the context in which the firm operates or inherent characteristics of the enterprise. Examples of descriptive classification variables include regulation level, product complexity, seasonality, and product mix/volume. However, some taxons are more prescriptive in nature because they reflect the firm's level of maturity attained against a generally recognized best practice. For example, there is virtually no dispute regarding the critical role leadership plays relative to strategy deployment or the important use of cross-functional teams. These categories reflect the firm's achievement in terms of commonly accepted best practices.

1.0 Business Environment		
	1.1 Competitive Environment	1.1.1 Intensity of Competition
		1.2.1 Stability/Emerging Threats
	1.2 Regulatory Environment	1.2.1 Product Regulations: Current & Prospective
		1.2.2 Process Regulations: Current & Prospective
	1.3 Market Conditions	1.3.1 Seasonality Effect
		1.3.2 Level of Growth
2.0 Leadership		
	2.1 Strategic Planning & Deployment	2.1.1 Formal Strategy
		2.1.2 Strategy Deployment
	2.2 Culture of Empowerment	2.2.1 Level of Participation
		2.2.2 Effectiveness of Participation
3.0 Customer / Market Focus		
	3.1 Translation of Requirements	3.1.1 Design/Order
		3.1.2 Feedback/Reaction
	3.2 Positioning / Value	3.2.1 Customer Value
		3.2.2 Dimensions of Performance
4.0 Information System & Knowledge Management		
	4.1 Access to Information & Knowledge	4.1.1 Availability to Data/Information to Support Decision Making
		4.1.2 Availability of Product/Process Knowledge
	4.2 Supportive of Improvement Efforts	4.2.1 Operations Data/Information
		4.2.2 Financial Data/Information
5.0 Human Resources		
	5.1 Maturity in Teaming	5.1.1 Level of Team Successes
		5.1.2 Team Qualities Considered Strongly in Hiring/Promotion
	5.2 Employee Skill Level	5.2.1 Cross Functional Encourgement
		5.2.2 Opportunties for Developing Additional Skills
6.0 Development of Products & Processes		
	6.1 Product Development	6.1.1 New Product Development Time
		6.1.2 Effectiveness of New Products Relative to Opportunity
	6.2 Process Development	6.2.1 New Process Development Time
		6.2.2 Effectiveness of New Processes Relative to Opportunity

7.0 Product & Process Characterization		
	7.1 Product Characterization	7.3.1 Product Lifetime
		7.3.2 Product Volume
		7.3.3 Product Complexity
		7.3.4 Product Variety
	7.2 Process Characterization	7.4.1 Process Capacity
		7.4.2 Layout of Processes
		7.4.3 Process Integration
		7.4.4 Process Bottleneck
		7.4.5 Process Type
	7.3 Product-Process Characterization	7.5.1 Hayes & Wheelwright Product-Process Structure
		7.5.2 Goldratt's VAT Logical Product-Process
		7.5.3 Relative Product-Process Complexity
8.0 Management of Extended Enterprise		
	7.1 Supply Chain Management	8.1.1 Management of Requirements (Product & Ordering)
		8.1.2 Management of Incoming Inventory
	7.2 Distribution Chain Management	8.2.1 Management of Finished Goods Inventory
		8.2.2 Management of Order Fulfillment
9.0 Approach to Continuous Improvement		
	9.1 Performance Measures	9.1.1 Strategic Alignment of Operational Measures
		9.1.2 Balanced & Multi-dimensional
	9.2 Process Focus	9.2.1 Key Process Identification
		9.2.2 Constraints
		9.2.3 Emphasis on Variability & CT Reduction
	9.3 Use of Specific World Class Practices	9.3.1 Formal Adoption of a CI Approach
		9.3.2 Demonstration of Effectiveness
	9.4 Quality System	9.4.1 Formal Registration
		9.4.2 Demonstration of Effectiveness
10.0 Enterprise Financial Health		
	10.1 Capital Availability	10.1.1 Capital Availability
	10.2 Liquidity	10.2.1 Cash Flow

Figure 3.12 Overview of the MET (version 2.0)

3.2.2 MET Based Assessment Survey Instrument

The on-site survey instrument was based on MET version 2.0. Of course, MET version 2.0 was developed based upon a synthesis of the summary of published literature on manufacturing performance and other published assessment instruments (e.g., MBNQA, Shingo, and LESAT).

A thorough discussion of this taxonomy is presented through its use as a survey instrument. While this taxonomy may serve other purposes in terms of a scheme useful for classifying manufacturing enterprises, the primary purpose of this taxonomy is to provide the basis for the development of a survey instrument to be used within an overall assessment methodology.

It is anticipated that the MET will continue to evolve as it is being used in the field. The objective of this research is to develop an initial MET, suitable for use within the proposed overall assessment methodology. There is much to be gained from the development of a standard taxonomy that could be applied consistently across a wide variety of manufacturers. This would greatly aid research into better understanding factors which influence manufacturing performance.

<u>3.2.2.1 Business Environment</u>

It is very important to understand the business environment in which the firm is operating. For the purposes of this research, this category is broken into three major aspects: competitive environment, regulatory environment, and market conditions. The scales are such that the higher the value the more positive the business environment.

1.0 Business Environment "descriptive"		Level 1	Score →	Level 5
1.1 Competitive Environment	1.1.1 Intensity of Competition	Numerous Competitors		Few Competitors
	1.1.2 Stability/Emerging Threats	Unpredictable Threats		Stable/ Few Threats
1.2 Regulatory Environment	1.2.1 Product Regulations	Many Regulations		Few Regulations
	1.2.2 Process Regulations	Many Regulations		Few Regulations
1.3 Market Conditions	1.3.1 Seasonality Effect	Heavy Seasonality		No Seasonality
	1.3.2 Level of Growth	No Growth/Shrinking		High Growth
Business Environment		**Average Score**		

Figure 3.13 MET 1.0 Business Environment

- *Competitive Environment* (1.1) – reflects the overall level of competition that the firm confronts in the markets it serves. A level 5 rating across all elements reflects the condition where the firm faces a relatively few number of competitors, competes in stable markets, faces few regulations, and a growing non-seasonal demand profile.
    - *Intensity of Competition (1.1.1) – A* score of "1" denotes the presence of many worthy competitors in which the client is perceived to have a sustained advantage. A score of "5" indicates that the firm faces few competitors and possesses a sustained advantage.
    - *Stability/Emerging Threats (1.1.2)* - a score of "1" indicates that the firm participates in markets which are known to experience frequent shifts due to unexpected arrival of threats (e.g., off shore competition, trade policies, disasters,

disruptive technologies, etc.). A sore of "5" indicates that markets have historically been relatively stable and few new threats are perceived.

- *Regulatory Environment (1.2)* – this evaluates the level of regulations faced by the firm due to state and federal requirements. While certainly all companies face compliance with these types of standards, clearly some (e.g., pharmaceutical industry) face higher levels of scrutiny then others (e.g., commodity). This should influence how the firm values compliance and standardization.
    - *Product Regulations (1.2.1)* - A score of "1" represents a high level of regulation regarding product features. A sore of "5" represents a low level of regulation regarding product features.
    - *Process Regulations* (1.2.2) - A score of "1" represents a high level of regulation regarding features of the manufacturing processes. A score of "5" represents a low level of regulation regarding product features.
- *Market Conditions* (1.3) - this characterizes the demand profile facing the firm. This should influence how the firm views such attributes as capacity (via seasonality and high levels of growth) and cost management.
    - *Seasonality Effect* (1.3.1) – A score of "1" indicates that firm participates in markets which exhibit clear seasonality (e.g., Christmas, summer, etc.). A score of "5" indicates that no appreciable changes in demand occur across time.
    - *Level of Growth* (1.3.2) – A score of "5" references the case where the firm is engaged in high growth markets and is seeing commensurate sales growth. A score of "1" means that the firm is engaged in either mature (i.e., no growth markets) or declining markets.

Relevant References supporting this element include the following. LESAT, Shingo, and MBNQA all address the firm's business environment. All three published assessments reference the importance of the competitive environment. Only MBNQA addresses regulatory environment specifically in its preface. Most of the published work on manufacturing performance pre-supposes the importance of the business environment in terms of competition, threats, and market conditions. Some of these references show up under the general heading of strategy.

3.2.2.2 Leadership

A major consensus in the literature and popular business readings is the key role that senior leadership plays in setting the tone and direction for the enterprise. This is also reflected in each of the three published assessment instruments. The MET reflects the leadership attribute in primarily two dimensions. The first dimension is the level of maturity which is exhibited in terms of strategy development and deployment. The second dimension is the level of empowerment that employees possess and the transition of this empowerment in terms of delivering superior value to its customers.

2.0 Leadership *"prescriptive"*		***Score*** →		
2.1 Strategic Planning & Deployment	***2.1.1 Formal Strategy***	"All Things to All"		Clear: Porter's Generic Strategy
	2.1.2 Deployment	Few Know / Little Involvement		Widely Understood & Clear Link to Actions
2.2 Culture of Empowerment	***2.2.1 Level of Participation***	Restricted Involvement		High Level of Involvement
	2.2.2 Effectiveness of Participation	Little Evidence of Impact		Evidence of Substantial Impact
Leadership		***Average Score***		

Figure 3.14 MET 2.0 Leadership

- *Strategic Planning & Deployment (2.1) –* This refers to an overall evaluation of how the senior leadership goes about strategy development and deployment. Strategy reflects the maturity of the firm in targeting a competitive advantage and embedding the right actions and structure in order to achieve it.
    - *Strategic Planning (2.1.1) – A* score of "5" denotes that a formal strategy has been developed (in terms of Porter's generic strategies). This indicates that the firm has made conscious choices about what actions should and should not be taken. A score of "1" indicates that the firm has really no coherent strategy and attempts to be "all things to all customers."
    - *Strategy Deployment (2.1.2) -* a score of "5" indicates that there is clear evidence that the strategy is known and acted upon throughout all levels of the enterprise. A score of "1" indicates that while the strategy might exist on paper, little evidence that the formal strategy drives actions and behaviors.
- *Culture of Empowerment (2.2)* – this evaluates the level of empowerment that employees exhibit in the accomplishment of their daily work. Do behaviors and attitudes exist which indicate that employees are driven by customer value rather than by strict conformance to standard tasks? This element is closely tied to attributes of teaming within the organization.
    - *Level of Participation (2.2.1)* - A score of "5" represents a high level of level of participation across organizational levels. A score of "1" represents a low level of level of participation across organizational levels.
    - *Effectiveness of Participation* (2.2.2) - A score of "5" represents a high level of effectiveness, which means that not only are employees participating there is

objective evidence that they are effective in terms of contributing the firm's performance. A sore of "1" indicates that there is little to no evidence of effectiveness.

Relevant References supporting this element include the following. The theme of the importance of leadership is found throughout the literature. Specifically Sakakibara, et. Al. (1997) and Flynn et. al. (1997) both explicitly deal with leadership variables. Also the element of strategy is exceptionally well represented in the literature (e.g., Morita and Flynn, 1997; Miller and Roth, 1994; Sakakibara et. al., 1997; Gilgeous, 2001, Ketokivi and Schroeder, 2004; Sum. et. al., 2004; and Porter, 1985). Underscoring the importance of the empowerment element are references within two of the published assessments: Shingo Prize, and MBNQA criteria.

3.2.2.3 Customer/ Market Focus

Clearly, the firm must understand their customers and consistently deliver value. This is commonly reflected in the popular literature, academic literature, and other published assessment methodologies. A clear understanding of customer value is critical to the firm's ability to identify waste (i.e., those activities that the customer is not willing to pay for). Also, reflected in this taxon is the effect of strategy deployment.

3.0 Customer / Market Focus "prescriptive"		Level 1	Score →	Level 5
3.1 Translation of Requirements	3.1.1 Design/Order	Informal / Unstructured		Intentional and Formal
	3.1.2 Feedback/Reaction	Few Know / Little Involvement		Widely Understood & Clear Link to Actions
3.2 Positioning / Value	3.2.1 Customer Value	No Clear Way to Identify (Informal)		Clearly Drives All Actions (Structured)
	3.2.2 Dimensions of Performance	No Sense of Relative Priorities		Clear Understanding
Customer/ Market Focus		Average Score		

Figure 3.15 MET 3.0 Customer/Market Focus

- *Translation of Requirements* (3.1) – This reflects two aspects. First, is how is the firm doing relative to transferring the customer's requirements into the product design and order fulfillment? How well are we doing listening to the customer reactions and longer term needs?
    - *Design/Order* (3.1.1) – The results of the value producing processes are reflected in this element. A firm which has an intentional method for translating needs into requirements achieves the highest level of performance (i.e., score of 5). However, if on the other hand the firm relies heavily upon an unstructured approach then there is a high probability that customer requirements will not be translated accurately (i.e., score of 1).
    - *Feedback/Reaction* (3.1.2) – If no systematic method exists for determining how well the firm is doing in terms of satisfying customer needs through the design and manufacturing activities then a low score is received (i.e., score of "1"). If,

however, there is clear evidence that the customer's feedback is listened to and shapes new actions in terms of the value producing processes of design and manufacturing then a high score is achieved (i.e., score of "5").

- *Positioning / Value* (3.2) – This element reflects how well customer value is connected to actions and a clear understanding of the relative importance of different dimensions of performance.
    - *Customer Value* (3.2.1) – If customer value is clearly identified and there is strong evidence regarding how customer value shapes the firm's activities then the client will receive a high score (i.e., score of "5"). If there is no clear way to identify how customer value drives actions then the client receives a low score (i.e., score of "1").
    - *Dimensions of Performance* (3.2.2) – Firms that score high (i.e., score of 5) on this element indicate that in the design and execution of the value producing business processes (i.e., product and manufacturing) there is a clear sense of the relative priorities (i.e., customer needs filtered through the firm's strategy). If, on the other hand, there is no relative sense of priorities, then the firm receives a low score (i.e., score of 1).

Relevant References supporting this element include the following. All three assessment methodologies strongly reflect the need for firms to be focused on market requirements and customer needs. Both the Shingo Prize and MBNQA weight heavily these issues dealing customer focused outcomes (approximately 20% of available points). In the published literature, Lowe et. al. (1997) show that higher performing plants are able to respond quicker to changes as requested by the customer. Of course, issues of the relative value of the multiple dimensions of performance show up in much of the publications dealing with strategy, such as Sum et. al., 1994;

Ghalayini and Noble, 1986, White, 1996; Ketokivi and Schroaeder, 2004; Das, 2003; Laugen et. al., 2005.

3.2.2.4 Information System & Knowledge Management

The important role of information systems to manufacturing has been abundantly documented in the literature. This taxonomy attempts to distill the complex subject of the relationship between information system and manufacturing as outlined below. The two major attributes involve the ready access to information/ knowledge and the level of support that this access provides to enable process improvement efforts.

4.0 Information & Knowledge Management *"descriptive"*			Score →	
4.1 Access to Information & Knowledge	***4.1.1 Availability of Data to Support Decision Making***	Difficult to Obtain & Interpret		Readily Available & Understood
	4.1.2 Availability of Product/Process Knowledge	Difficult to Obtain & Interpret		Readily Available & Understood
4.2 Supportive of Improvement Efforts	***4.2.1 Operations Data/Information***	Difficult to Obtain & Interpret		Readily Available & Understood
	4.2.2 Financial Data/Information	Difficult to Obtain & Interpret		Readily Available & Understood
Information & Knowledge Management		***Average Score***		

Figure 3.16 MET 4.0 Information and Knowledge Management

- *Access to Information & Knowledge* (4.1) – This element characterizes the *relative efficiency* of accessing the data and information. This construct may be generally referred to as "availability" and is broken own into the following components. One component deals with the knowledge of processes and product knowledge and the other deals with any other data required to support decision making.

- *Availability of Data to Support Decision Making (4.1.1)* – Firms that score low (i.e., score of "1") on this dimension may possess the data; but regularly find it difficult, if not often impossible to access within a timely manner. Conversely, a high score reflects the condition where decision makers routinely access key data within a time horizon acceptable for decision making (i.e., score of "5").
- *Availability of Product/Process Knowledge (4.1.2)* – Firms that score high (i.e., score of "5") on this element have developed a relatively efficient means for capturing and retrieving knowledge about the firm's products and processes. Note that this does not necessarily imply an extensive Product Lifecycle Management system, but includes dissemination of key product/process knowledge throughout the enterprise through a variety of means (e.g., posting of standard work, one point lessons, line side PC workstations to guide inspection paths, etc.). Firms that score low (i.e., score of "1") on this measure are characterized by the lack of availability of critical product and process information within a timely manner. For example, key pieces of information may exist in the minds of key personnel but are not formally documented and therefore are not generally available.

- *Supportive of Improvement Efforts* (4.2) – The element deals with the *relative effectiveness* of the data to guide and support improvement efforts. Two types of data are of concern: data that summarizes financial activity and data that describes operational concerns.
  - *Operations Data/Information (4.2.1)* – A firm that scores high (i.e., score of "5") posses operational data in a manner that effectively guides continuous improvement efforts. A firm that scores low (i.e., score of "1") presents

operational data in a manner that is not effective in terms of guiding ongoing improvement actions.

- *Financial Data/Information* (4.4.2) - A firm that scores high (i.e., score of "5") effectively uses financial data to guide continuous improvement efforts. A firm that scores low (i.e., score of "1") does not effectively use financial data to drive ongoing improvements. A firm that scores high posses financial data in such a way that it is easy to obtain, easy to interpret, and available to those requiring it to guide improvement efforts. A firm that scores low on this element reflects the case where data is difficult and time consuming to obtain and once obtained is not easy to interpret.

Relevant References supporting this element include the following. All three assessment methodologies reflect the importance of information systems and knowledge management. The MBNQA specifically refers to the importance of data availability, accuracy, integrity and timeliness. These issues reflect about 5% of the available points with Balridge. Also it is clearly referenced in LESAT (i.e., two lean practices). This element is listed in the Shingo Prize specifically as "knowledge management system" under the general heading of "Leadership and Infrastructure"). Also, Shingo briefly mentions MIS under the category of supporting functions. The published research also reflects a similar emphasis as all three assessment methodologies (e.g., Henderson et. al., 2004; Kaplan, 1984; Das, 2003; Goldratt, 1984; Noreen et. al., 1985). Ghalayni et. al. (1996) conclude characteristics of important measures and data include such things as support for daily decision making, facilitation of understanding by employees, encouragement of improvements rather than monitoring, change as required by the business.

3.2.2.5 Human Resources

Even with advances in automation, manufacturing is an inherently human endeavor. The consensus of both the business and academic literature confirms this notion. This taxonomy focuses on two major aspects: the skills of employees and the ability to work cooperatively within a team environment.

5.0 Human Resources *"prescriptive"*		Level 1	Score →	Level 5
5.1 Maturity in Teaming	***5.1.1 Level of Team Success***	Limited / Informal		Frequent / Formal
	5.1.2 Qualities Considered in Hiring/Promotion	Task Skills dominate		Balance Between Task & Teaming Skills
5.2 Employee Skill Level	***5.2.1 Level of Cross Functional Mastery***	Primarily within function		Mastery of a variety of skills is widely deployed
	5.2.2 Mastery of Key Skills	Not identified and/or inexperience		Identified & clear strengths exist
Human Resources		***Average Score***		

Figure 3.17 MET 5.0 Human Resources

- *Maturity in Teaming* (5.1) – this reflects the relative level of success which has occurred through individual participation within teams. Also included is the degree to which personal characteristics, conducive to team work is recognized and rewarded.
    - *Level of Team Success* (5.1.1) – For a firm to score a "5" on this element they should be able to share numerous recent success stories related to the use of teams. Teams include both multifunctional participation and a cross section of employees from up and down the organizational structure. These success stories

should include measurable business results across a broad set of performance measures. It is essential to probe beyond whether or not teams are used but drill down to find out the impact of teams.

  - *Qualities considered in Hiring and Promotion* (5.1.2) – For firms to score high (i.e., score of "5") on this element, there should be strong evidence that characteristics beyond functional subject matter expertise is rewarded. The ability to work collaboratively is highly valued.

- *Employee Skills* (5.2) – This element focuses on the level of employee skills in critical subject matter areas, across all levels of the firm.

  - *Level of Cross Functional Mastery* (5.2.1) – Firms that score high on this element have employees that are continually adding to their skill base by acquiring new skills in other functional areas. Firms that score low are characterized by relatively little exposure to other departments, and employees tend to stay within their natural domains for an extended time.

  - *Mastery of Key Skills* (5.2.2) – In order for teams to work effectively, not only should the team reflect a multifunctional perspective, but the team must be populated with sufficient subject matter expertise in key areas. These key areas differ by firm but may include product design, manufacturing engineering, tool and die, automation, etc.

*Relevant References supporting this element include the following.*Clearly, all three assessments address the importance of developing human resource capability. Targeting this attribute, LESAT specifically identifies eight lean practices, MBNQA and Shingo both attribute almost 10% of the total available points to this attribute. Shingo specifically mentions empowerment, use of teams, suggestions systems, and reward and recognition. The Baldridge criteria discusses the need for a human resource focus in terms of promotion of teamwork, empowerment, learning and growth, employee well being and satisfaction. Within the published research literature Flynn (1997) showed that infrastructure practices (including specific variables of workforce management and work attitudes) are of high importance. Similar findings by Sakakibara et. al. (1997) found that workforce management variables are significant. Also Ketokivi and Schroeder (2004) found that cross training and workforce cooperation are significantly related to particular measures of performance. Das (2003) found that combining lean initiatives with such variables as reliance on teams and decentralized decision making are most effective in leveraging investments in advanced technologies.

3.2.2.6 Development of Products & Processes

The ability to be responsive to customer needs and requirements is enhanced by a responsive and effective new product development process. Concurrently, the manufacturing processes need to be developed in order to effectively deliver new products so that customer value is maximized.

6.0 Development of Products & Processes "prescriptive"		Score: Level 1	→	Level 5
6.1 Product Development	6.1.1 New Product Development Lead-Time	Inferior to Competition		Superior to Competition
	6.1.2 Effectiveness of Product Development	Inferior to Competition		Superior to Competition
6.2 Process Development	6.2.1 New Process Development Lead-Time	Inferior to Competition		Superior to Competition
	6.2.2 Effectiveness of New Process Development	Inferior to Competition		Superior to Competition
Development of Products & Processes		Average Score		

Figure 3.18 MET 6.0 Development of Products and Processes

- *New Product Development* (6.1) – This attribute includes both the lead-time it takes to introduce new products and the effectiveness with which these products are delivered.
  - *6.1.1 New Product Development Lead-Time* – This refers to the time it takes for new products to move from concept to manufacturing implementation. A level 5 indicates that the firm is faster and more responsive than their competition.
  - *6.1.2 Effectiveness of Product Development* - It is one thing to rapidly introduce new products, but it is equally important to introduce them effectively. A firm which scores high on this element shows evidence of a seamless integration of

the new product in manufacturing without excessive quality problems and production problems.

- *6.2 Process Development* – This attribute reflects the time it takes to develop new more competitive manufacturing processes and the level of effectiveness of their introduction.
  - *6.2.1 New Process Development Time* - This refers to the time it takes to introduce new processes into making either existing or new products. A level 5 indicates that the firm is faster and more responsive than their competition.
  - *6.2.2 Effectiveness of Process Development* - A firm which scores high on this element shows evidence of a seamless integration of the new manufacturing process without excessive quality problems and production problems.

Relevant References supporting this element include the following.

Interestingly, both the literature and the published assessments offer more empirical evidence regarding the need for product development than process development.

In LESAT, five lean practices relate to both product and process development. Shingo specifically calls out the need for for innovations in product design and development. Baldridge mentions the need for process development within their "value creation" category. Also Laugen et. al. (2005) found evidence that rapid new product development belonged in the class of best practices. Morita and Flynn (1997) show that speed to market is one of the differentiators between world class firms and those that are not. Ketokivi and Schroeder (2004) found that design for manufacturability was primarily associated with fast delivery and low cycle times.

3.2.2.7 Product & Process Characterization

An essential aspect of describing the manufacturing enterprise is to characterize their products, type of processes, and their interaction.

7.0 Product & Process Characterization "descriptive"		Level 1	Score →	Level 5
7.1 Product Characterization	7.1.1 Product Lifetime	Short		Long
	7.1.2 Product Volume	Low		High
	7.1.3 Product Complexity	Low		High
	7.1.4 Product Variety	Low		High
7.2 Process Characterization	7.2.1 Process Capacity	Excess		Minimal
	7.2.2 Layout of Processes	Functional		Cellular
	7.2.3 Process Integration	Low		High
7.3 Product-Process Characterization	7.3.1 Goldratt's VAT	Unclear Fit		Clear Fit
	7.3.2 Hayes-Wheelwright Matrix	Unclear Fit		Clear Fit
Product & Process Characterization		Average Score		

Figure 3.19 MET 7.0 Product & Process Characterization

- *Product Characterization* (7.1) – this attribute includes the relative product lifetime, volume, complexity, and variety. Strong empirical evidence suggests these are important features of the firm relative to explaining manufacturing performance.
    - *Product Lifetime* (7.1.1) – A firm that has relatively long lifetimes (e.g., wholesale plumbing) indicates that rarely does the company introduce new products. It may be more important to probe and determine whether or not there

is clear evidence that the lifetime is changing (i.e., shortening) rather than based upon some absolute standard.

  - *Product Volume* (7.1.2) – A firm that primarily focuses on a relatively few high volume products typically within a limited number of product options would receive a high score.
  - *Product Complexity* (7.1.3) – a high score indicates an engineered to order product, or at least products that have a relatively large number of features and performance parameters.[150]
  - *Product Variety* (7.1.4) – a high score indicates those firms whose products have a possesses a large number of end item options.

- *Process Characterization* (7.2) – this attribute includes such elements as whether or not the firm possesses excess capacity, how the processes are laid out, and level of value stream integration.
  - *Process Capacity* (7.2.1) – a high score represents those firms that are using a high percentage of available capacity.
  - *Layout of Processes* (7.2.2) – a low score indicates a functionally driven layout where "like processes" are grouped together and each type is managed separately. A high score indicates the presence of cellular manufacturing where equipment is grouped based upon a product focus.

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[150] In future versions of the MET, it is recommended to swap the anchors for the product complexity element (7.1.3). This is in light of the research by MacDuffie et. al. 1996 which indicated the presence of a high level of complexity tends to reduce manufacturing performance.

- *Process Integration* (7.2.3) – a low level of integration means that most of the core processes which characterize the value chain are found outside the plant. In these cases, the SME provides primarily joining and assembly functions. A high level of integration means that the SME's manufacturing processes are generally deep with respect to processing steps.

- *Product-Process Characterization* (7.3) – Goldratt's VAT construct and Hayes-Wheelwright's Process-Product matrix have shown to be helpful ways to characterize the joint product-process relationship.
    - *Goldratt's VAT* (7.3.1) – A high score represents a clear fit and low score represents an unclear fit.
    - *Hayes-Wheelwright Matrix (7.3.2) -* A high score represents a clear fit and low score represents an unclear fit.

Relevant References supporting this element include the following. LESAT lists a total of 22 lean practices which are relevant to what is termed "process focus." The Shingo Prize references the importance of the process in terms of their major category titled "WCM Operations and Processes" which was worth 25% of their total available points. MBNQA identifies an element termed "process management" which accounted for almost 10% of its available points. In addition, numerous references in the literature stress published research regarding the importance of characterization of products and processes. Lowe et. al. (1997) show the effect of process automation depends upon the type of plant. MacDuffie et. al., (1996) indicated that the plant's ability to handle product variability depends on the process. Henderson et.al. (2004) showed that the combination of "hard-side" and "soft-side" process improvements impacted some measures of performance. Also relevant are VAT analysis developed by Goldratt (Cox and Spencer, 1998) and the process-product matrix developed by Hayes and Wheelwright (1979)

3.2.2.8 Management of Extended Enterprise

Much attention has been given in the business literature to the importance of the entire value chain of activities that must take place both inside and outside the walls of the plant. The task of managing across multiple businesses both on the supply side and the distribution side is referred to as the extended enterprise.

8.0 Management of Extended Enterprise *"prescriptive"*		***Level 1***	***Score*** →	***Level 5***
8.1 Supply Chain Management	***8.1.1 Product Requirements***	Unclear		Clear
	8.1.2 Ordering & Inventory Requirements	Unclear		Clear
8.2 Distribution Chain Management	***8.2.1 Finished Goods Management***	Unclear		Clear
	8.2.2 Order Fulfillment Management	Not meeting Customer Desires		Regularly Meeting Customer Desires
Management of Extended Enterprise		***Average Score***		

Figure 3.20 MET 8.0 Management of Extended Enterprise

- *Supply Chain Management* (8.1) – This attribute includes probing on how the company communicates product and order requirements to its suppliers. Also the relative efficiency of the supply chain should be determined.

- *8.1.1 Product Requirements (8.1.1)* – This includes such items as joint involvement in product design, Bill of Material accuracy, obsolescence, engineering changeovers, etc.
- *Ordering and Inventory Requirements* (8.1.2) – This includes determining the stability of forecasts, length of forecast window, etc. This should include on-going efforts to reduce supply side inventories.

- *Distribution Chain Management* (8.2) – this attribute reflects how the company operates in and through its distribution and transportation channels, including two distinct yet overlapping components: the management of finished goods and the fulfillment of customer orders. Of ultimate concern is how and how well the company is performing with respect to lead-times, logistics costs, finished good inventories at various stages, etc.
  - *Finished Goods Management* (8.2.1) – This element is concerned with how finished goods are managed beginning with completed product at the plant and ending with receipt by the customer. This includes an evaluation of the relative efficiency of the inventories and assets within the distribution chain (i.e., multiple echelon warehouses, turns of finished good inventories, warehouse management systems, etc.) in order to satisfy customer demand. A low score indicates that the company is "wasteful" in terms of how the finished good assets are managed. A high score reflects the case where the company manages finished goods in a highly efficient manner (relative to inventory turns and resource costs).
  - *Order Fulfillment Management* (8.2.2) – This element is concerned with how and how well the company meets customer requirements on a per order basis. This includes how well the plant's schedule is synchronized with the real needs of its ultimate customers (i.e., lead-times, performance to stated lead-times) as well as

the integrated system of freight carriers (i.e., in terms of damage, cost , and timeliness). A high score means that the company almost always meets customer expectations, while a low score indicates that customer needs are not regularly met on a per order basis.

Relevant References supporting this element include the following. LESAT references three lean practices in terms of managing the supply chain. The Shingo Prize references the need to "partner with suppliers and customers." The publication by Lowe et. al. (1997) concludes high performing plants tended to operate within high performing supply chains. Flynn et. al. (1997) found certain infrastructure variables were significant, including "supplier relationships."

3.2.2.9 Approach to Continuous Improvement

Since the assessment is concerned with finding opportunities to increase enterprise performance, it is essential to understand where the firm stands relative to commonly accepted norms regarding continuous improvement. While there are certainly many successful approaches to continuous improvement, there is consensus regarding essential elements that any continuous improvement strategy must possess. The following elements are focused on determining how the firm stands relative to these attributes.

9.0 Approach to Continuous Improvement "Prescriptive"		Level 1	Score	Level 5
9.1 Performance Measures	9.1.1 Strategic Alignment of Operational Measures	Fuzzy Connection		Clearly Articulated
	9.1.2 Balanced & Multi-dimensional	Single Dimension (e.g., cost)		Multi-Dimensional & Balanced
9.2 Process Focus	9.2.1 Identification of Key Processes	Unsupported		Documented & Communicated
	9.2.2 Constraints	Unknown		Known & Managed
	9.2.3 Emphasis on Variability & CT Reduction	None		Drives Action
9.3 Use of World Class Practices	9.3.1 Continuous Improvement Approach	Informal		Formal & Intentional
	9.3.2 Effectiveness	Unclear		Clear & Documented
9.4 Quality System	9.4.1 Formal System	Informal & Unstructured		Formal & Registered
	9.4.2 Effectiveness	Conformance Driven		Performance Driven
Approach to Continuous Improvement		Average Score		

Figure 3.21 MET 9.0 Approach to Continuous Improvement

- *Performance Measures* (9.1) – one of the major findings of the last couple of decades is that measurements cannot be viewed strictly from a financial standpoint. The measures must be aligned to strategic goals of the firm and should reflect multiple dimensions of performance.
    - *9.1.1 Strategic Alignment of Operational Measures* – A firm that scores high on this element can illustrate clearly how their operational measures support the enterprises strategy. A low score indicates that there is a low level of linkage

between operational measures and strategy. Recall, strategy is about choices that the firm makes in terms of how to compete.

  - *9.1.2 Balanced and Multi-dimensional* – A firm which scores high on this element consistently manages against a broad set of operational measures. These measures include, but are not limited to cost, quality, and delivery.

- *Process Focus* (9.2) – Value from the perspective of the customer is the result of a series of steps (i.e., processes) that the manufacturer must perform. This attribute reflects the level of maturity that the firm possesses, in terms of its ability to focus on specific key steps from the perspective of cost, quality, and delivery.

  - *Identification of Key Processes* (9.2.1) – processes which are responsible for controlling key outcomes (e.g., critical to quality characteristics, flexibility to adjustments in customer demand) should be clearly understood and managed.

  - *Constraints* (9.2.2) – The critical role that the constraint plays relative to leveraging throughout and plant labor cost on a per unit basis should be clearly understood. The constraint operation should be managed accordingly.

  - *Emphasis on Variability Reduction & CT Reduction* (9.2.3) – A firm that scores high understands the critical linkage between variability reduction, cap on WIP, and the joint effect on lead-time reduction within the plant.

- *Use of World Class Practices* (9.3) – Numerous practices are generally recognized in the literature as being associated with world class levels of performance. These include, but are not limited to, the following: SMED, 5S, Pull, and Six Sigma.

  - *Approach to Continuous Improvement (9.3.1)* - A high score reflects the condition where the firm is using a relatively formal approach to continuous improvement. This includes the use of formal team charters, recognized role of facilitation, formal training and use of tools and techniques.

  - *Effectiveness* (9.3.2) – A high score indicates that the firm can show consistent results associated with its focused continuous improvement efforts.

- *Quality System* (9.4) - This attribute reflects the importance of the firm having both a formal documented quality system and clear evidence demonstrating its relative effectiveness.

  - *Formal System* (9.4.1) – a firm that scores high on this element shows evidence that a formal and documented quality system both exists and is adhered to. Evidence of this includes ISO 9000 and or TS 16949 registration.

  - *Quality System Effectiveness* (9.4.2) – A firm that scores high on this element shows evidence that corrective actions are root cause oriented and effective. This includes consistent improvement in measures relating to quality, including increasing ability to meet customer requirements (including both product and non-product).

Relevant References supporting this element include the following. The LESAT approach referenced the need for lean tools within the overall theme of "enabling infrastructure." Of course, the Shingo Prize mentions frequently the need to apply lean tools, particularly under the heading "World Class Manufacturing Operations and Processes." Similarly, MBNQA emphasizes the need for establishing a formal process for improving organizations excellence. Gilgeous (2001) found that it takes multiple improvement efforts to drive improvements in a performance dimension like quality. Laugen et. al. (2005) posited that best practices should be thought of as "bundles" or action programs which were a group of practices. Flynn et. al. (1997) found that a significant interaction occurred between quality practices and JIT practices and there was a need to separate mature and immature applications of these practices. Also Davies and Kocchar (2002) found that the effect of best practices were context specific and should positively impact all dimensions of performance. Numerous publications reflect the strategic role of constraints (e.g., Goldratt, 1984; Cox and Spencer, 1998). Also numerous publications reflect the importance of specific lean practices (e.g., Schonberger, 1986).

3.2.2.10 Enterprise Financial Health

It is important to understand the financial condition of the firm relative to its ability to obtain required resources. The objective within this element is not to determine exact knowledge of the firm's financial state, but to identify whether or not its core operations are being affected by the firm's financial condition.

10.0 Enterprise Financial Health *"Descriptive"*		***Level 1***	***Score →***	***Level 5***
10.1 Ability to Invest in Assets	***10.1.1 Capital Availability***	Not Possible / Severely Restricted		Adequate
10.2 Liquidity	***10.2.1 Cash Flow***	Severely Restricted		Sufficient
Enterprise Financial Health		***Average Score***		

Figure 3.22 MET 10.0 Enterprise Financial Health

- *Ability to Invest in Assets (10.1)* - This ability can come from a variety of sources (e.g., cash in the bank, available credit, and overall profitability).
    - *Capital Availability (10.1.1)* – A high score on this element means that the firm has adequate means to acquire needed capital in order to invest in worthwhile projects. A low score indicates that the firm either has no ability to attract investment capital or that its ability is severely restricted.
- *Liquidity* (10.2) - This reflects the firms ability to pay current expenses. This attribute reflects the overall profitability of the firm both in terms of the magnitude of net profits and return on investment.
    - *10.2.1 Cash Flow* – A high score means that the company is not having to constrict basic operations due to the lack of sufficient cash flow. A low score indicates that the firm's core operations are regularly restricted due to lack of cash flow.

Relevant References supporting this element include the following. The work of the National Research Council (1993) mentioned one of the barriers to success for small manufacturers was lack of access to capital and operating funds.

Representing the fit of the client within the overall MET taxonomy is illustrated in Figure 3.23. This example star chart indicates a firm that operates within a relatively difficult business environment, relatively immature in terms of key human resource practices, and immature in terms of continuous improvement practices. On the positive side the example company has a strong focus on its customers and markets.

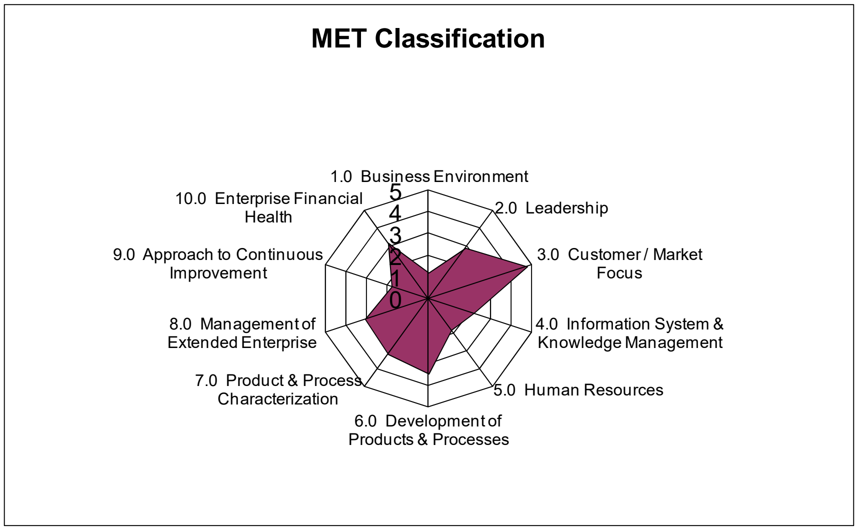

Figure 3.23 Example Graphical Representation of Fit within the MET

3.3 Production Systems Taxonomy (PST)

One of the major challenges facing the development of an overall assessment methodology is the systematic classification of "best practices" or the solution space from which prescriptions will be selected. This research has termed this the Production System Taxonomy (PST). Based upon the literature review, a relatively small amount of research has been published in the area of systematically classifying best practices for the manufacturing enterprise. However, the taxonomy of manufacturing practices developed by Bolden (1997) was particularly helpful in characterizing the best practice solution space. A modest modification was made to this taxonomy to serve as the PST within the TBAM approach.

3.3.1 Review of Bolden's Taxonomy

Several publications were found attempting to classify "best practices." Clearly the population of possible prescriptions is quite large. Also, researchers have commented that there is some ambiguity concerning exact definitions of these practices and their interrelationships.

Particularly helpful, in terms of its breadth and organization, is the taxonomy produced by Bolden et. al. (1997). Bolden's classification scheme for development of his taxonomy is shown in the Figure 3.24 and explained in the following narrative.

Bolden et. al.'s objective was to identify and classify "modern manufacturing practices" in order to be used to guide selection of studies for future studies. They attempt to identify practices at similar levels of specificity. Their objective is not be so specific that it becomes (e.g., MRP II) and not so vague as to make it difficult to understand (e.g., manufacturing systems). This work found, after an exhaustive literature review and a review conducted by a multidisciplinary team, a total of 87 practices. These practices are classified according to two broad dimensions - "strategic emphasis" and "problem domain."

The "strategic emphasis" includes two primary areas: "business focus" and "organizational focus." The business focus represents the competitive priorities dealing with cost, quality, and responsiveness. Therefore, all practices with the specific aim of one of these performance measures fall into these categories. The "organizational focused" strategic emphasis is used for classifying those practices that target increasing the capabilities as a whole (i.e., these practices support all three areas – cost, quality, and responsiveness). According to this scheme, these practices tend to relate primarily to the development of technology or employees.

The second major dimension used to classify manufacturing practices is the "problem domain." And this reflects the specific area in which the practices primarily operate. The areas are identified as design/production, inventory/stock, work organization, and wider organization.

Bolden et. al.'s taxonomy of 87 manufacturing practices is summarized in the Figure 3.24 below. Note each cell within the matrix is referenced (e.g., practices found in 1.A tend to be conducted within "design and production" with the business focus of improved quality.) so it can be used as a reference later when comparing this research to other more recent attempts at developing a list of best practices. Since one of the challenges is clear definition of practices, Bolden provides a clear definition for each of the 87 practices.[151] Some of the advantages provided by this taxonomy, according to the authors, are as follows.

- This type of taxonomy "helps to identify systematic commonalities and differences between manufacturing practices and techniques."[152]
- "One of the main aims of the taxonomy is to promote clarity and understanding within an area which increasingly runs the risk of becoming fragmented and confusing."[153]
- This taxonomy has the potential to prompt future research within manufacturing.
- "Finally, the taxonomy might prove useful to managers. For example, it provides a basis for carrying out an audit of practices within a company, as well as for comprehensively benchmarking the company against competitors, suppliers, and customers." [154]

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151 Bolden, Richard, Waterson, Patrick, Warr, Peter, Clegg, Chris, and Wall, Toby, "A New Taxonomy of Modern Manufacturing Practices", International Journal of Operations and Production Management, Vol. 17, No. 11, 1997, pp. 1126 – 1130.

152 Ibid., pp. 1123

153 Ibid.

154 Ibid., pp. 1124

Problem Domain	***Strategic Emphasis***				
	Business Focus			**Organization Focus**	
	A. Improved Quality	**B. Reduced Cost**	**C. Responsiveness to Customer**	**D. Improved Technology**	**E. Employee Development**
1. Design and Production	Quality Standards SPC TPM QFD Poke-Yoke	Reduced WIP JIT Production Process Mapping Smart Design Re-usability Product Rationalization	Rapid prototyping Concurrent engineering Customer involvement in design LT reduction Agile manufacturing	CAPP CIM Automation CAD & engineering	Job Rotation Multi-Skilling Psychromterics Appraisal Training & development Suggestion schemes Attitude surveys Secondments Safety management
2. Inventory and Stock	Supply Chain Partnering Customer Feedback Conformance Checks	Reduced Inventory Single Sourcing JIT Inventory Control Forecasting Logistics Management	Predicting customer requirements Maintaining stock levels	Automated storage & retrieval systems EDI	Product team (purchasing and distribution)
3. Work Organization	Quality improvement teams Operator responsibility Quality feedback to operators Quality training Ergonomic design	Downsizing De-layering Outsourcing Casual labor	Flexible work organization After sales support Cellular manufacturing	FMS Group Technology Computer co-operative work MRP	Harmonization Team based work Job Enrichment Boundary Management
4. Wider Organization	Total quality management Quality awards Quality gurus World class manufacturing Benchmarking for quality	Lean production Cost management Financial performance Time based management Benchmarking: costs	Priority given to customers Market research Customer surveys Benchmarking for customer responsiveness BPR	Technology strategy Computer based management tools Benchmarking for technology	HRM strategy Empowerment Performance based pay Culture change Learning climate Investors in people Bench people effectiveness

Figure 3.24 Bolden's Taxonomy of Manufacturing Practices

3.3.2 Modification of Bolden's Taxonomy: PST Development

This research expands upon Bolden's Taxonomy by analyzing it in light of more recently published work, both from the academic and from the popular business literature. The overall classification scheme used by Bolden is retained; however, particular practices have been scrutinized for clarity and sufficiency. The result is a slightly modified listing and classification of best practices.

Particularly relevant in this task are the publications by Sakakibara et. al. (1997), Gilgeous (2001), and Laugen et. al. (2005). Figure 3.25 cross references the best practices identified within these articles, with respect to Bolden's taxonomy (reference to Bolen's taxonomy is shown in parentheses). Bolden's taxonomy does a reasonably good job classifying these practices.

Improvement Programs Reference: Gilgeous (2001)	**Action Programs** Laugen, et. al. 2005	**JIT & Infrastructure Practices** Sakakibara, Flynn, et. al. (1997)
Manufacturing Lead-Time Reduction (1.C)	Process Equipment (1.D)	Set-up time reduction (NF)
JIT (1.B)	Manufacturing Capability (NF)	Scheduling Flexibility (3.C)
Introduction of FMS, Introduction of CAD/CAM (3.D, 1.D)	Process Automation (1.D)	Maintenance (1.A)
Develop New Process for Old & New Products (NF)	IT/ERP (3.D)	Equipment Layout (3.C)
Capacity Expansion, Recondition of Physical Facilities (NF)	E-business (2.D)	Kanban (2.B)
Reducing Size of Workforce, Plant Relocation or Closing (3.B)	Supplier Strategy (2.A)	Supplier relationships (2.A)
Management Training (4.E, 3.E)	Outsourcing (3.B)	Product Design (1.B, 1.C)
Worker Training (1.E, 4.A)	Process Focus (3.C)	Workforce Practices (E.1, E.3, E.4)
Worker Safety (1.E)	Pull Production (2.B)	Organizational Characteristics (NF)
Worker Broad Skill Range (1.E)	Quality Management (3.A, 4.A)	Quality Management (1.A, 3.A, 4.A)
SQC (1.A)	Equipment Productivity (1.A)	Manufacturing Strategy (NF)
Vendor Quality (2.A)	Workplace Development (3.E)	
Zero Defects (NF)	New Product Development (1.B, 1.C)	
Quality Circles (3.E)	Environmental Compatibility (NF)	
Preventative Maintenance (1.A)		
Integrating Systems Across Areas & within Manufacturing (3.E)		
Improving New Product Introduction Capability (1.C)		
Note: the code in parenthesis is the reference to Bolden's taxonomy. The code "NF" denotes not found.		

Figure 3.25 Fit of Bolden's Practices with Respect to Recent Best Practice Literature

In addition, the above classifications represent a cross section of the categories of practices used by Bolden. Also shown in Figure 3.26, almost all of Bolden's major attributes categories appear to be represented in these three lists of best practices. This review provides us with a strong indication that Bolden's taxonomy appears to be useful in organizing independent sets of best practices.

Recent "Best Practices" Literature and Bolden's Taxonomy Reference: Bolden et. al., 1997					
Problem Domain	***Strategic Emphasis***				
	Business Focus			**Organization Focus**	
	A. Improved Quality	**B. Reduced Cost**	**C. Responsiveness to Customer**	**D. Improved Technology**	**E. Employee Development**
1. Design and Production	Gilgeous (2001) – 2 practices Laugen et. al. (2005) – 1 practice Sakakibara et. al. (1997) – 2 practices	Gilgeous (2001) – 1 practices Laugen et. al. (2005) – 1 practice Sakakibara et. al. (1997) – 1 practice	Gilgeous (2001) – 2 practices Laugen et. al. (2005) – 1 practice Sakakibara et. al. (1997) – 1 practice	Gilgeous (2001) – 1 practices Laugen et. al. (2005) – 1 practice	Gilgeous (2001) – 3 practices Sakakibara et. al. (1997) – 1 practice
2. Inventory and Stock	Gilgeous (2001) – 1 practices Laugen et. al. (2005) – 1 practice Sakakibara et. al. (1997) – 1 practices	Laugen et. al. (2005) – 1 practice Sakakibara et. al. (1997) – 1 practice		Laugen et. al. (2005) – 1 practice	Sakakibara et. al. (1997) – 1 practice
3. Work Organization	Laugen et. al. (2005) – 1 practice Sakakibara et. al. (1997) – 2 practices	Gilgeous (2001) – 1 practices Laugen et. al. (2005) – 1 practice	Laugen et. al. (2005) – 1 practice	Gilgeous (2001) – 1 practices Laugen et. al. (2005) – 1 practice	Gilgeous (2001) – 3 practices Laugen et. al. (2005) – 1 practice
4. Wider Organization	Gilgeous (2001) – 1 practices Laugen et. al. (2005) – 1 practice Sakakibara et. al. (1997) – 1 practice				Gilgeous (2001) – 1 practices Sakakibara et. al. (1997) – 1 practice

Figure 3.26 Relationship of Best Practice Literature and Bolden's Taxonomy

The Figure 3.27 illustrates items found in the recent academic literature and in popular literature that were not specifically mentioned within Bolden's taxonomy. This information was used to justify a modest update to Bolden's taxonomy to reflect the importance of these practices.

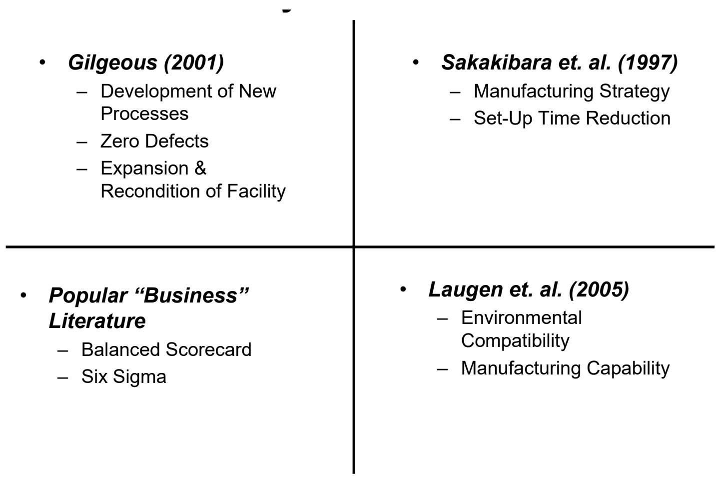

Figure 3.27 Best Practices Not Found in Bolden's Taxonomy

Based upon this research, the following modifications have been made to Bolden's list of best practices. Some of the items Bolden identified were dropped for lack of external support within other literature sources and some were dropped due to redundancy with other elements. Also, some of the practice names were changed to enhance clarity. Finally, a few new practices were added due to their large presence within the literature (e.g., SMED, Six Sigma, and Balanced Scorecard). These modifications are summarized in the Figure 3.28 below.

- ***Eliminate – due to lack of literature support***
  - “Investors in People”
  - Quality Guru’s
  - JIT Production due to redundancy
- ***Change “title” – in order to enhance clarity, maintain Bolden’s definition.***
  - From “World Class Manufacturing” to “Internationally Competitive”
  - From “Harmonization” to “Reduce Status Barriers”
  - From “Smart Design” to “Design for Manufacturability”
  - From “Casual Labor” to “Flexible Labor Force”
  - From “Priority Given to Customers” to “Customer Focus”
  - From “Secondments” to “Staff/Management Rotation”
  - From “Computer based Management Tools” to Decision Support Systems
  - From “Product Rationalization” to “Value Engineering”
- ***Additions – due to large presence in either the academic or popular literature***
  - Set-Up Time Reduction
  - New Process Development
  - Balanced Scorecard
  - Six Sigma
  - Environmental Compatibility
  - Link Manufacturing to Enterprise Strategy

Figure 3.28 Modifications to Bolden’s Best Practices

The resulting modified list of best practices classified according to Bolden’s taxonomy is documented in Figure 3.29. This is the taxonomy that serve as the PST within the TBAM assessment framework.

It is noted that the concern of this research is not the development of in any sense “optimal” classification of best practices, but the use and development of a scheme that is useful within the context of manufacturing assessments.

Modification of Bolden's Taxonomy of "Best Practices"					
Problem Domain	***Strategic Emphasis***				
	Business Focus			**Organization Focus**	
	A. Improved Quality	**B. Reduced Cost**	**C. Responsiveness to Customer**	**D. Improved Technology**	**E. Employee Development**
1. Design and Production	Quality Standards SPC TPM QFD Poke-Yoke	Reduced WIP JIT Production Process Mapping Design for Manufacturability Re-usability Value Engineering	Rapid prototyping Concurrent engineering Customer involvement in design LT reduction Agile manufacturing SMED	CAPP CIM Automation CAD & engineering New Process Development	Job Rotation Multi-Skilling Psychromterics Appraisal Training & development Suggestion schemes Attitude surveys Staff/Management Rotation Safety management
2. Inventory and Stock	Supply Chain Partnering Customer Feedback Conformance Checks	Reduced Inventory Single Sourcing JIT Inventory Control Forecasting Logistics Management	Predicting customer requirements Maintaining stock levels	Automated storage & retrieval systems EDI	Product team (purchasing and distribution)
3. Work Organization	Quality improvement teams Operator responsibility Quality feedback to operators Quality training Ergonomic design	Downsizing De-layering Outsourcing Flexible Labor Force	Flexible work organization After sales support Cellular manufacturing	FMS Group Technology Computer co-operative work MRP/ERP	Reduce Status Barriers Team based work Job Enrichment Boundary Management
4. Wider Organization	Total quality management Quality awards Internationally Competitive Benchmarking for Quality	Lean production Cost management Financial performance Time based management Benchmarking: costs Balanced Scorecard Link Mfging to Strategy	Customer Focus Market research Customer surveys Bench. for customer Responsiveness BPR	Technology strategy Decision Support Sys. Technology Benchmarking Environmental Compatibility Six Sigma	HRM strategy Empowerment Performance based pay Culture change Learning climate Investors in people Bench people effectiveness

Figure 3.29 Modification of Bolden's Taxonomy for Use as PST

3.4 Development of Assessment Methodology

This section describes the development of an overall assessment methodology, including introducing the overall evaluation-diagnosis-prescription framework and defining each of the major TBAM steps. This development while drawing upon aspects found within other published assessment methodologies (i.e., MBNQA, Shingo Prize, and LESAT) attempts to go beyond their almost exclusive focus on evaluation. Explicit attention is given to the critical issues of identifying barriers to increased performance and formulation of recommendations.

The practice of assessments generally falls into one of two categories: evaluation driven and recommendation driven. As previously discussed, the published assessment methodologies tend to be evaluation driven. This means that the overriding objective of these approaches is based upon how the firm's practices fit or "measure up" against an external reference model (e.g., MBNQA, Shingo Prize, and LESAT). While certainly helpful, evaluation driven assessments do not formally translate into recommendations. On the other hand, many consultants peddle assessment tools which predispose a "solution set" and therefore spend little effort on either evaluation or careful characterization of the firm. Nevertheless, recommendations stemming from powerful manufacturing paradigms (e.g., Toyota Production System, Theory of Constraints) often are very beneficial. However, the concern is that these recommendations arise more from the assessor's prior commitments than based on the actual condition of the firm. These prior commitments may arise from adherence to a particular production system theory or from even the advocacy of a particular improvement tool that (e.g., SMED, SPC, DBR, TPM, etc.).

The current practice of assessments is disjointed at best and is certainly not holistic. The evaluation driven approaches tend to not deal directly with the problem of formulating recommendations. The recommendation driven approaches tend to not rely upon a careful evaluation of the firm

One of the goals of this research is to develop a theoretical framework for linking evaluation and prescription aspects of the assessment into an overall methodology. This research proposes that in order to accomplish this objective a third element, diagnosis, must be considered. Diagnosis serves to logically link the evaluation and prescription phases of the assessment. The diagnosis stage relies upon information obtained during the evaluation stage to logically construct cause-effect relationships. The objective of diagnosis is to identify the relatively small set of root causes that appear to be limiting performance. The prescription stage of the assessment attempts to develop a set of recommendations that targets the elimination or reduction of root causes.

Therefore, the proposed assessment methodology is based upon the linking of the foundational elements: *evaluation, diagnosis*, and *prescription*. These elements are briefly defined as follows.

- *Evaluation* – the identification of where a firm and its practices compare to an externally defined standard or fit within a taxonomy.
- *Diagnosis* - The determination of root cause(s) which result in barriers to increased performance.
- *Prescription* – The identification of specific recommendations which if implemented will lead to improved performance.

3.4.1 Proposed Assessment Framework (E-D-P Cycle)

Since the business environment is constantly changing and the appropriateness of recommendations is time dependent, the assessment methodology can be thought of as a continuous process. Each stage of the assessment can be thought of as part of a continuous improvement cycle. It is proposed that the following Evaluation-Diagnosis-Prescription (E-D-P) cycle, depicted at a high level in Figure 3.19, provides a useful overall framework for the assessment.

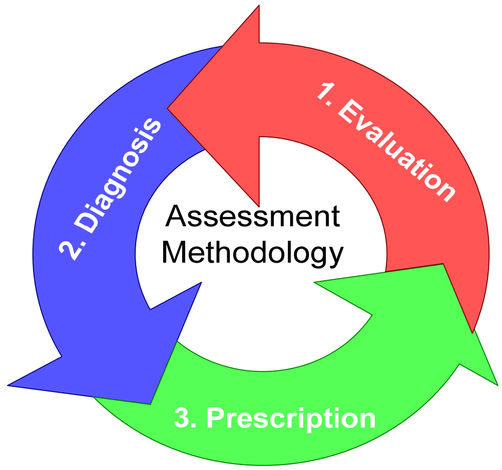

Figure 3.30   Assessment Methodology (E-D-P Cycle)

A brief introduction is provided for each of the three phases within the assessment methodology.

Evaluation – The primary objective of this phase is to determine where the firm currently fits with respect to important manufacturing enterprise characteristics. These important characteristics result from two major sources; the published literature on manufacturing performance and previously published assessment methodologies. This research posits that these characteristics can be organized within an overall taxonomy, termed the Manufacturing Enterprise Taxonomy (MET). The proposed MET includes both descriptive elements (i.e., elements which primarily attempt to characterize the firm) and prescriptive elements (i.e., elements which indicate the firm's maturity in terms of known best practices). This taxonomy serves as the basis for an on-site survey instrument so that the assessors determine where the company fits within the MET. Also, this survey instrument enables the assessors to identify the undesirable effects that the company is currently experiencing. The overall purpose of the evaluation stage is to develop a concise abstraction of the "facts" about the SME.

The evaluation stage is similar to a medical doctor first seeking to determine a patient's vital signs and symptoms (i.e., undesirable effects) before moving into determining cause (i.e., diagnosis) and developing a prescription for returning the patient to health.

Diagnosis – This stage focuses on developing the logical linkage of undesirable effects with root cause(s) which prevent increased performance. *The intuition required to develop the logical linkages is enabled from insight gained from conducting the classification of the firm within the MET.* It is anticipated that the development of these cause and effect linkages will involve joint participation between an assessment team and representatives from the client.

When dealing with enterprise-wide cause and effect issues, the diagnostic tool must be very flexible to model the variety of relationships that might exist. Also the tool cannot be overly complicated so that the client, typically not trained in the tool, can easily participate in the tool application. The Current Reality Tree (CRT), one of the tools found within Goldratt's Thinking Process, was selected for illustrating the required cause and effect logic.[155] The CRT was found to do a better job reflecting multiple types of cause and effect relationships while still remaining very readable. Consideration was given to such tools as 5 Whys, Cause and Effect Diagrams, and FMEA.[156]

The CRT begins with Undesirable Effects (UDEs) and logically progresses through effect-cause-effect logic until a singular or set of root causes emerge. The results are presented in a tree diagram, where the UDEs are represented as "leaves", the intermediate "cause and effect"

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155 William H. Dettmer's Goldratt's Theory of Constraints" pg 60-80, provides a useful introduction to the Thinking Process and to the Current Reality Tree.

156 The Six Sigma Handbook, Thomas Pyzdek, 2003, McGraw-Hill, New York, NY, pp. 261, 265.

relationships are represented as "branches" and the root cause are represented as the "root." The validity of the cause and effect relationships results from the process of scrutinizing the tree (i.e., using the categories of legitimate reservation).[157] The CRT is developed jointly between the assessor and the client. It is critical for the assessor and the client to have a common understanding of the core problem(s) facing the firm.

The diagnosis stage is similar to a doctor identifying the root cause of a patient's symptoms. Once the cause has been determined, only then can the doctor consider alternatives and prescribe an accurate prescription that targets improvement of the patient's health.

Prescription – This element focuses on developing a set of recommendations which appears to most appropriately address the root cause(s) that were identified during the diagnosis stage. The development of these recommendations is guided by a taxonomy of best practices drawn from the research literature, termed Production Systems Taxonomy (PST). The assessment team selects a relatively small set of prescriptions, from a larger set of possible prescriptions found within the PST. The PST selection is accomplished based on the perceived relationship to the previously identified root causes. It is proposed that an assessor's judgment can be greatly aided by a clear organization of possible prescriptions from which a limited number can be selected. The purpose of the PST selection is to guide formulation of recommendations.

The prescription stage is analogous to a doctor prescribing a remedy, which targets the elimination of the underlying root causes of the patient's poor health. The goal of prescription is to improve the patient's health.

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[157] Dettmer, W.H., Goldratt's Theory of Constraints: A Systems Approach to Continuous Improvement, ASQC Quality Press, Milwaukee, Wisconsin, 1997, pp. 26.

3.4.2 Summary of Assessment Framework

A brief summary is provided in Figure 3.31 that illustrates the overall framework within which the assessment methodology is developed. Figure 3.31briefly describes the objectives for each stage and the core instrument and/or tool that is used at each stage.

Framework for Assessment Methodology		
Evaluation	**Diagnosis**	**Prescription**
Objective: • Characterization of the firm and its competitive environment. • Identification of Undesirable Effects (UDEs)	***Objective:*** Capture cause and effect relationships that explain UDEs so that root cause(s) to increased performance are illustrated.	***Objective:*** Determine set of recommendations which target root causes
Tool: Manufacturing Enterprise Taxonomy (MET) Survey	***Tool:*** Goldratt's Current Reality Tree (CRT)	***Tool:*** Production System Taxonomy Selector (PST)

Figure 3.31 Framework for Assessment Methodology

Before the assessment methodology can be further developed the taxonomies referenced in the above table must be fully developed. The final section presents a detailed review of the entire taxonomy based assessment methodology (TBAM).

3.4.3 Development of Taxonomy Based Assessment Methodology

This section details which comprises the TBAM approach by providing a step-by step overview of the methodology.

3.4.3.1 Overview

As previously discussed the assessment framework includes three stages: Evaluation, Diagnosis, and Prescription. This section draws upon the previously developed taxonomies (MET and PST) and adds detail to the framework resulting in a thoroughly defined taxonomy based assessment methodology (TBAM).

The overall purpose of the evaluation stage is to develop a concise abstraction of the "facts" about the SME. The specific objective of the evaluation stage is to identify the client's fit within the manufacturing enterprise taxonomy (MET) and its highest priority undesirable effects (UDEs). This is accomplished through a 1-2 day on-site survey which scores the company across 55 sub elements defined within the 10 major MET taxons. Anchored scoring assists the assessors in consistent application of the ratings. Recall that these elements were defined based upon the body of literature relating practices and factors to standards of generally recognizable performance. The MET serves as a basis for the assessment team to discover the interrelationships and dynamics within the company. Much of the results of the evaluation stage are graphed on a radar chart, where the score within each major classification variable is represented on a corresponding axis. This provides a graphical snapshot of the current state of the SME.

The last step of the evaluation stage includes the identification and prioritization of undesirable effects (UDEs) that the client is currently experiencing.

The objective of the diagnosis stage is to translate the UDEs into root causes(s) through the use of the Current Reality Tree (CRT). The CRT was developed by Goldratt and was described in the earlier literature review chapter. The CRT begins with UDEs and progresses through effect-cause-effect logic until a singular or set of root causes emerge. The results are presented in a tree diagram, where the UDEs are represented as "leaves", the intermediate "cause and effect" relationships are represented as "branches" and the root cause are represented as the "root." The validity of the cause and effect relationships results from the process of scrutinizing the tree (i.e., using the categories of legitimate reservation).[158] The development of the CRT and validating the CRT is the result of close collaboration between the assessment team and the client.

In order for the assessment to be successful it is critical for the assessor and the client to have a common understanding of the core problem(s) facing the firm.

The objective of the prescription stage is to develop a set of recommendations that target elimination of the root causes that were identified during diagnosis and guided by the most appropriate elements selected from within the PST. The elements within the PST are selected by the assessment team through a multi-voting exercise. In general, the highest rated elements are selected. A general rule of thumb is that the elements which represent 80% of the multi-vote are selected. These selected elements are then used to guide the development of the recommendations.

The schematic of this TBAM approach is illustrated in Figure 3.32.

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[158] Dettmer, W.H., Goldratt's Theory of Constraints: A Systems Approach to Continuous Improvement, ASQC Quality Press, Milwaukee, Wisconsin, 1997, pp. 26.

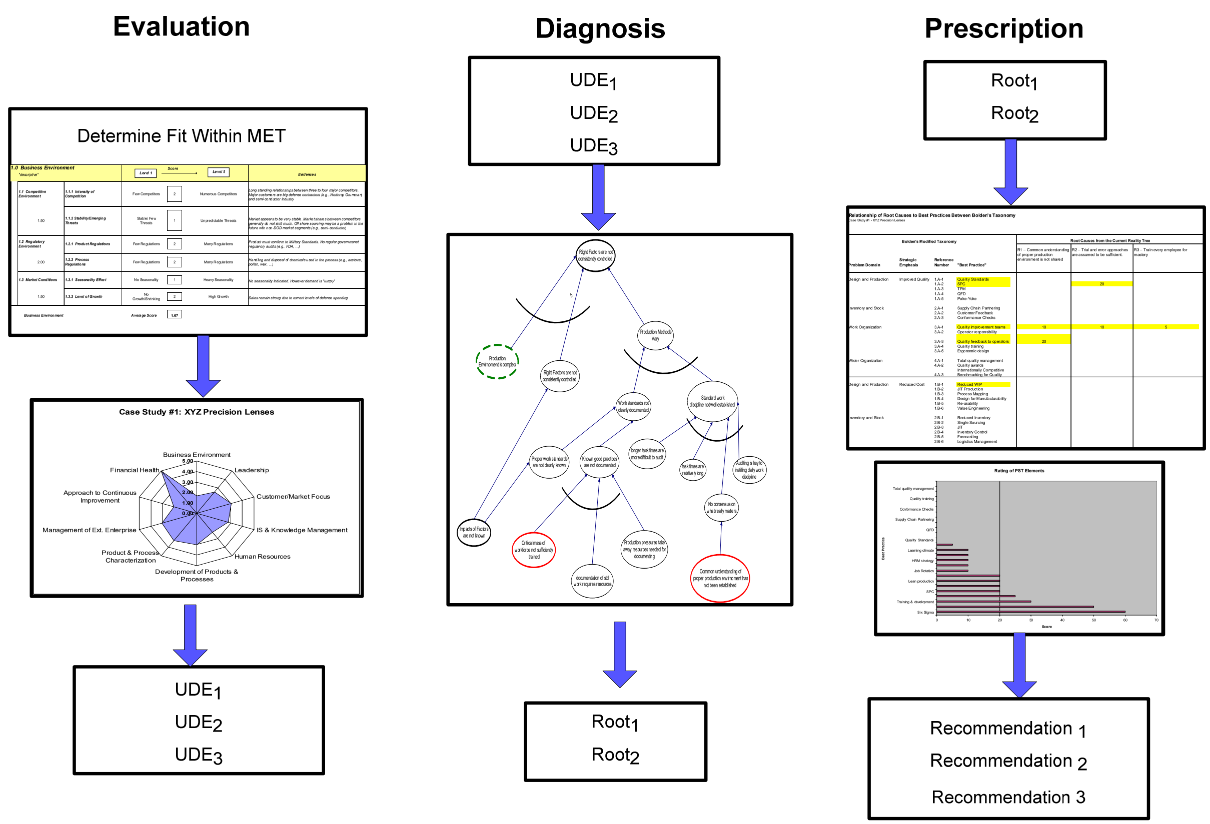

Figure 3.32 Overview of Taxonomy Based Assessment Methodology (TBAM)

3.4.3.2 Definition of Each Step within TBAM

Each step within the assessment methodology is defined using the flowchart in the Figure 3.33. This research does not assert that the elements contained within this methodology are in any sense "optimal." Clearly, both the overall framework and each element can be improved upon. The objective of this research is to present an overall assessment methodology based upon both taxonomies of manufacturing enterprises (MET) and best practices (PST). The methodology as defined should be considered as a first generation. Additional work and research remains regarding how basic elements and steps could be best linked together.

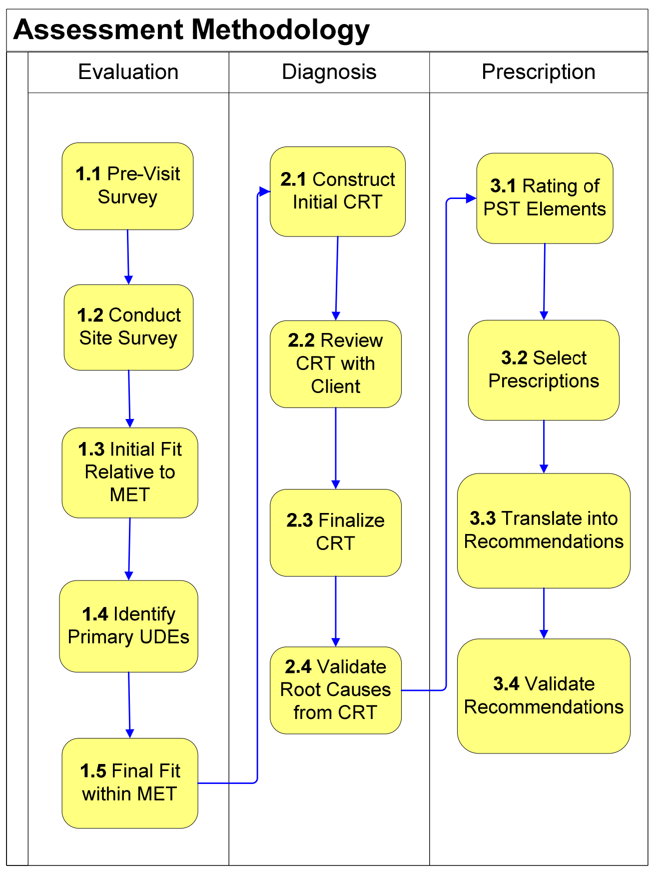

Figure   3.33 Steps within TBAM

Following the description of each step are observations of key aspects of the steps which were added after the completion of the three case studies. The purpose of the observations is to provide additional insight into practical concerns involved in using the methodology.

The Evaluation stage is summarized as follows.

Pre-visit Survey (1.1) – The MET based survey instrument is provided to the client prior to the site visit. This enables the client to review the survey, gather relevant materials, and assemble the appropriate people in preparation for the site visit.

Conduct Site Survey (1.2) – The MET based survey instrument is used by the assessors. The assessors use the anchored scale to rate the client across each of the 55 MET sub elements. Reasons for establishment of specific ratings are given. The collection of these ratings across all elements establishes the client's fit within the MET. Throughout the survey, probing questions are asked in order to more fully understand the client's situation and to identify the key relationships and dynamics which are present. It is recommended that at least two external assessors be used, so that the lead assessor can drive the discussions and the other assessor focus on keeping good notes.

Initial Fit to MET (1.3) – Once the assessment has been completed then the assessor(s) should determine the fit within the MET classification including both descriptive and prescriptive components. Appropriate documentation is produced which serves as justification for the appropriate classification of the firm within the MET. Also graphical portrayal of the classification should be produced (i.e., radar chart).

Identify Primary UDEs (1.4) – During the plant visit, probing will include the identification of undesirable effects (UDEs) that the firm is currently experiencing. For each of the 10 major taxons the UDEs are identified and noted by the assessment team. At the end of the on-site visit, the client is asked to multi-vote across all of the UDEs so that the top three UDEs are identified for use during the diagnosis phase.

Final Fit to MET (1.5) – Based upon a review of the initial fit within the MET and identification of UDEs the client is briefed on these findings. Since it is possible that certain aspects of the operation were not correctly understood during the initial visit, this provides the client an opportunity to correct factual errors. The final fit is validated by the assessment team after the client review is completed. It should be noted that while final MET fit is the responsibility of the assessment team, it is important to establish agreement with the client. The following observations about the Evaluation stage are noted.

- The approach seemed to effectively document the assessment team's judgments regarding the state of the client at the time of the assessment relative to attributes which are deemed important with respect to their impact on manufacturing performance.
- Visualization of the client's fit across multiple dimensions is accomplished by reviewing radar charts.
- The value of the scores for the MET survey, was not so much the actual numerical rating, but the resulting discussion which revealed the underlying relationships which exist within the company. This was found to be enormously helpful to the assessment team as it constructed the CRT.

The Diagnosis stage is summarized as follows.

Construct Initial CRT (2.1) – The initial CRT is constructed based upon the UDEs obtained from step 1.4. It is advisable that the assessment team develop an initial "strawman" CRT. This serves the purpose of instructing the client participants in how to read and scrutinize

CRTs. It is almost always helpful to have more than one person involved in the development and refinement of the CRT.

Review CRT with Client (2.2) – The initial tree must be reviewed by senior client leadership. This serves as a check on validity of the CRT. The use of the CRT should result in a relatively small (i.e., one to three) root cause set that logically account for the firm's major UDEs. The ultimate objective is to gain consensus between the assessors and the client's senior leadership with respect to the tree logic representation.

Finalize CRT (2.3) – Make any needed changes to the CRT based upon feedback from the review with the client. The suspected roots should lie either within the client's senior management representatives span of control or sphere of influence. However, in order to preserve independence the ultimate completion of this step is the responsibility of the assessor.

Validate Root Causes from CRT (2.4) - It is important to obtain a level of validation from the client on the final version of the CRT, since the root causes from the CRT drive the selection of prescription and ultimately the recommendations within the prescription stage. It is extremely important for the assessor and the client to come to a consensus regarding the firm's root causes to barriers for increased performance. The following observations about the CRT are noted.

- The CRT should be developed from the perspective of the client's senior management representative (SMR).
- One of the critical aspects to the use of the CRT is how do you know when you have it a root cause.
- Typically if more than one root cause is found, then it is not uncommon for one of the root causes to be primary in terms of their greater influence on explaining UDEs.

The Prescription stage is summarized as follows.

Rating of PST Elements (3.1) – The assessment team multi-votes each element of the PST across the set of root causes identified during the diagnosis stage. Since there are 95 elements in the PST, it is useful for the assessment team to have the definitions of each element readily available.

Select Prescriptions (3.2) – The highest ranked prescriptions are then selected based upon the ratings and the assessor's experience. In cases where more than one root cause exists, the total score for each PST element is obtained by summing across the votes received for each root cause. The general rule of thumb is to select the top scoring elements until 80% of the cumulative scores are obtained. There is a many-to-many relationship between the prescriptions selected and the root causes identified. For example, multiple prescriptions can be focused on one root cause or multiple root causes can be associated with one prescription.

Translate into Recommendations (3.3) – Since the prescriptions found within the PST are generic, these prescriptions should be verbalized into recommendation statements that have particular meaning within the context of the firm. These recommendations should be rooted and generally guided by the selected prescriptions. However, the recommendations should not be artificially limited by the selected prescriptions either. The content of the recommendations should exhibit a high degree of clarity and conciseness in addition to being focused on elimination of specific root causes, guided by the selected prescriptions.

Validate Recommendations (3.4) – The recommendations are then shared with the client. The client should be given an opportunity to react to the initial recommendations before finalizing them. Once the assessment team has completed its development of the recommendations, the client should be given the opportunity to provide feedback in terms of effectiveness and implementability.

General observations about the PST are noted as follows.

- The PST used within this methodology includes 95 elements and even for highly experienced assessors the exact definitions are not always clear. Therefore, it is recommended that a reference document that includes elemental definitions be readily available throughout the assessment period.
- If from the CRT there is a dominant UDE then the selection of prescriptions and ultimately the recommendations should reflect the relative difference in importance among root causes.

CHAPTER 4

CASE STUDIES

This chapter is to describes results from piloting the TBAM assessment methodology. The sections describe the purpose of the case studies, development of the field guide, case study protocol, selection of the participating SMEs, and an overview of the case study conduct. The major emphasis of this chapter is the presentation in narrative form of each of the three case studies. Following the case studies is a review of the cases including a critique and list of enhancements to the TBAM approach that resulted from the field piloting activity. Three companies agreed to serve as pilots. In order to preserve confidentiality, these companies are referred to as Alpha, Beta, and Gamma.

4.1 Purpose of the Case Studies

The objective of the case study pilots is to provide direct feedback from the field in terms of how the TBAM approach works in the field. Based on this feedback, changes and enhancements are made to TBAM. These insights and corresponding changes are discussed at the end of this chapter. Overall, the field experiences provided a level of credibility and confidence in the methodology relative to its practicality. The cases studies are documented in a common format, which served as the basis for presentation to a review panel. The review panel interacted with the cases so that preliminary measures of reliability and validity were obtained.

The long term goal is to develop the TBAM methodology that allows the entire assessment to be accomplished within a one week time period. The targeted assessment timeline indicating key activities is shown in Figure 4.1. The one week goal and related timeline was not the specific objective of the pilots, which were principally focused on obtaining feedback from the field from the use of the methodology. However, progress toward that one week objective was observed as the case studies were conducted. The first case study Alpha took a period of seven weeks, while the last case study Gamma required only a 2 week time period. A specific objective of the cases was for the research to identify the most difficult and challenging aspects of TBAM so that enhancements can be targeted as future research extensions. Clearly, the biggest challenge identified by the case study work was the development and validation of the client's current reality tree (CRT).

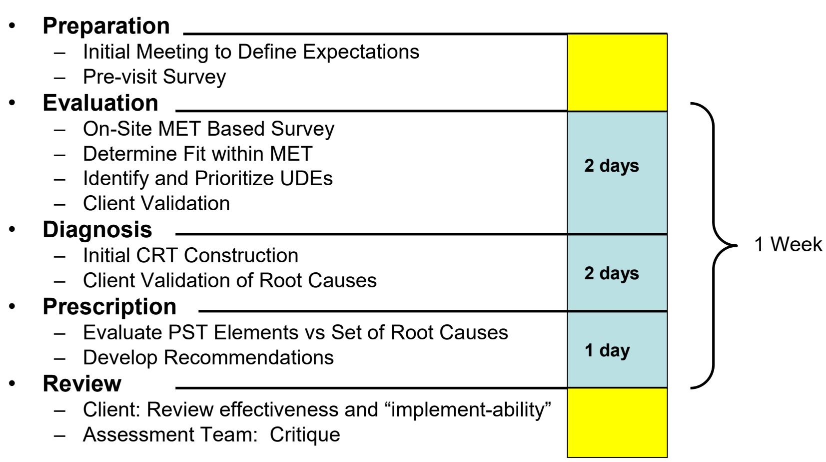

Figure 4.1   Targeted Assessment Timeline

The following lists some of the key questions regarding the assessment methodology that the pilot case studies were focused on attempting to answer. These questions are answered at the end of this chapter.

- How much time is required from both the client and the assessment team's standpoint to complete the TBAM process?
- What changes should be made to the TBAM methodology during the case study and why? Also if these changes were implemented what were their effects?
- Were there any difficulties associated with using the anchor scoring defined within the MET based survey? If so, what changes should be considered?
- Were any challenges encountered that might become barriers to other possible client's use of the methodology? Any suggestions about overcoming barriers?
- Does the assessment team have enough intuition about the client after the on-site evaluation stage is completed to construct a reasonable CRT?
- How much of the client's time was needed to get the CRT to the point of validation?
- Did any problems surface during the selection of PST elements in relationship to root causes? If so, then what are the suggestions for refining either the PST or the element selection approach?
- What areas of future research should be focused on in order to reduce the resource level and timeframe for conducting the assessment?

4.1.1 Development of Field Guide

A field guide was developed in order to prepare the assessment team[159] and the client for the piloting of the methodology within the field. This guide served several multiple purposes as outlined below.

- Training of team members in accordance with the IRB protocol.
- Ensure consistency across each of the three case studies.
- Sets a more detailed expectation for the clients.
- Facilitates the on-site survey through ready reference of all needed material.
- Location for all relevant notes and information obtained during the pilot.

Each member of the assessment team was given a copy of the field guide. Also the senior management representative from the participating client was given a copy as well. The field guide contains the following specific items.

- Overview charts which illustrate the TBAM approach, A brief written summary of TBAM methodology and reference materials.[160]
- Opening Agenda which serves as the general guide for the 1-2 day on-site visit.

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[159] Special thanks is expressed for the work of assessors Robert Sheely, Travis Hill, and Steve Puryear.

[160] These materials include a review of Porter's generic strategies and its relationship to the TBAM approach, short explanations of the Hayes-Wheelwright Process-Product Matrix and Goldratt's VAT structure.

- MET based survey instrument which includes elemental definitions and scoring guidelines. Also, the instrument provides an opportunity for noting underlying observations and reasons or the particular scores.
- Worksheet for the identification and prioritization of UDEs.
- A brief introduction to the Current Reality Tree (CRT) and Entity Legend.
- A worksheet is provided for use when multi-voting elements of the PST. In addition, the PST definitions are given which serve as a ready reference during the multi-voting process.
- A worksheet is provided for use during the formulation of recommendations, which shows the linkages between root causes and selected best practices.
- Blank informed consent forms for both the senior management representative and each participant in accordance with IRB protocol.

An example of the opening agenda is found in the figure below. This agenda is used to ensure that the right people are made available during the assessment's team on-site and that the most efficient use of the client's time is accomplished during this period.

Survey Section	Typical Participants
1.0 Business Environment	CEO, VP of Marketing, Plant Manager
2.0 Leadership	CEO, VP of Marketing, Plant Manager
3.0 Customer / Market Focus	VP of Marketing, Engineering Manager, Plant Manager
4.0 Information & Knowledge Management	Engineering Manager, Plant Manager
5.0 Human Resources	HR Director, Plant Manager
6.0 Development of Products & Processes	Engineering Manager, Plant Manager, Quality Manager
7.0 Product & Process Characterization	Engineering Manager, Plant Manager, Quality Manager
8.0 Management of Extended Enterprise	Purchasing Manager, Scheduling, Plant Manager
9.0 Approach to Continuous Improvement	Plant Manager, Continuous Improvement Manager, Quality Manager
10.0 Enterprise Financial Health	Accounting Manager, Plant Manager

Figure 4.2 Typical Agenda for On-Site Survey

4.1.2 Case Study Protocol

Each case study is documented according to the format shown in Figure 4.3. This format is based, generally, upon the case study format used by Cox and Spencer, 1998. The purpose of the case study format is to clearly document the lessons learned which arise out of the pilot of the assessment methodology.

- **Introduction to Company**
- **Evaluation**
  - On-Site Survey Fit within MET
  - Identification of UDEs
- **Diagnosis**
  - Current Reality Tree (CRT)
  - Identification of Root Cause(s)
- **Prescription**
  - PST Selection: Relevant Guidelines
  - Development of Recommendations
- **Client Receptivity**
- **Critique of Methodology**

Figure 4.3 Case Study Documentation Format

The case study also documents the condition of the SME at the time the assessment was conducted, which serves as a basis for the subsequent presentation of the case to a panel review board. The review board provide responses that are used to to assess the TBAM methodology's reliability and validity.

An assessment team was used for each case study. The lead assessor for each of the case studies was the researcher. The lead assessor's primary task was to lead the client and the team through the each of the major steps of the methodology. The assessment team included the lead assessor and at least one additional member. Each member of the assessment team should be trained in the TBAM methodology. In addition, the lead assessor should possess extensive experience (i.e., at least 10 years) in leading improvements within a wide variety of SME's. In addition, the lead assessor must have a firm understanding of the virtually all the elements of the PST, and experience in implementing many of these best practices. The primary role of the other members of the assessment team is to ensure client responses are properly noted and to serve as a support to the lead assessor. The other assessors, in general, need to have a previous experience working within the manufacturing environment.

4.1.2.1 Selection of Participating Clients:

The selection of companies was not based upon random sampling, but based on specific criteria. These criteria included the client's interest and willingness to participate in the research pilot. The TBAM approach is very intensive and requires a significant time commitment, not just from the external assessment team, but from the manufacturing client. Thus it was essential that the company exhibit a willingness to participate as a pilot case study. In addition, the client agrees to abide by the research plan approved by the Internal Review Board in terms of ethical treatment of human subjects. The company is under no obligation to implement any of the recommendations stemming from the assessment.

Prospective companies were approached by the author. In one of the three cases (i.e., Beta), the author had conducted a small previous project. For the other two cases, neither the author nor any member of the assessment team had any substantial prior involvement with the company. Ultimately, an agreement was reached with three companies to serve as pilot sites. The identity of each company is confidential; therefore, they are referred to as cases Alpha, Beta, and Gamma. These companies met the requirements of the research and the conditions outlined by the approved IRB protocol for dealing with human subjects in a research setting[161]. The requirements are summarized below.

- Site must have less than 500 employees.
- Ensure the voluntary participation of key employees and that no negative consequence will result from an employee involvement in the research.[162]
- The company's Senior Management Representative (SMR) must be willing to agree to the conditions of the assessment. This includes the assumption of transparency and honesty during the conduct of the assessment. Transparency means that no line of reasonable inquiry is outside the bounds of the assessors and that responses are voluntary.
- The SMR agrees that if any of the employees become uncomfortable with the assessment they are free to withdraw. If at any point the employee decides to no longer participate in the pilot, then the company will not take any negative action against the employee.
- Allow the development of a written case study, which maintains the confidentiality of the company, for inclusion as part of a published research paper.

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[161] This research's protocol has been defined by the IRB Study #07-068 approved by Mississippi State University's Office of Regulatory Compliance on April 9, 2007

[162] Copies of all signed informed consent documents are available and maintained in compliance with the protocol established in IRB Study #07-068.

4.1.2.2 Brief Overview of Case Study Process

For each participating manufacturing firm, a senior management representative (SMR) is designated. This person receives the initial document describing the assessment research and the request to participate in the assessment as part of this research project.

Prior to Assessment: The researcher meets with the SMR in order to determine whether or not the firm is a candidate for the research pilot. The same recruiting documents are provided to each prospect. The firm's willingness to serve as a pilot location is determined. Once it is determined that the firm meets the participation requirements then the assessment is scheduled. The first step is to send the company a copy of the on-site survey instrument that will be used.

During Assessment: Once the assessment team is on-site, the assessment began with an opening meeting with the SMR and the key employees. Each person is briefly instructed regarding the potential risks and benefits of participation as outlined on the informed consent document. The subjects are asked if there are any questions and an opportunity provided to each subject to sign the informed consent document. The group and one-on-one sessions are scheduled based upon agreements made with the SMR.

Questions are asked using the MET survey instrument. Follow-up non-scripted questions are asked for clarification and to establish linkages. Questions are asked regarding "undesirable effects" (UDEs) that the firm currently faces. The client SMR is asked to prioritize (UDEs).

The assessment concludes with an ending group session, that typically includes all key employees. Either during that session or very soon after, the assessment team works with the SMR to validate the client's assessed fit within the MET. Also the researcher leads the development and client validation of the Current Realty Tree (CRT). The level of client participation in the CRT construction is a function of the level of interest and time available.

Generally, it is helpful to have client involvement in the CRT, especially since a key part of implementation of TBAM.

The assessment team multi-votes across each element of the Production Systems Taxonomy (PST) against each of the root causes identified from the CRT. The PST elements that receives the highest votes are then used as guidelines for the development of the set of recommendations. These recommendations are presented to the SMR for feedback in terms of effectiveness and implement ability.

Post Assessment: The case study was documented both graphically via PowerPoint and formally written. The principal investigator provided a final report "packet" to the client's SMR including both the PowerPoint documentation and the written case study. The packet includes the fit within the MET, applicable current reality trees, and a set of recommendations. The members of the panel were asked evaluate each of the cases and the overall methodology.

4.2 Case Study #1: Alpha

The entire case study is found in the Appendix F, whereas the discussion in this section is to illustrate the TBAM approach by providing a summary of findings across each of the three stages (i.e., Evaluation - Diagnosis- Prescription).

4.2.1 Introduction to Alpha

Alpha is a privately owned embedded hardware electronics company that focuses on rapidly developing and delivering customized solutions to its customers. This company has a strong engineering design oriented culture. Applications for its products are found in the telecommunications, automation, and heavy duty military computing applications. Manufacturing products include both single boards and system platforms. Alpha views its competitive strength as rapid response from concept to prototyping followed by effective transitioning into routine production. Many of its competitors, while very technically savvy, are quite large and unable to rapidly respond to changing customer needs.

The Figure 4.4 provides an overview of the members of the assessment team, the agreed upon scope of the assessment established by the lead assessor and the client's Senior Management Representative (SMR). Of particular significance to the scope, is that the client wanted to ensure that the assessment focused on how manufacturing was supporting the overall enterprise and, in turn, how the enterprise was supporting manufacturing. A brief overview of product offerings, markets, and the title of key employees involved in the assessment is also shown.

Overview of "Alpha" Case Study

May 21-22, 2007

Assessors: Clay Walden, Robert Sheely, Travis Hill (Mississippi State University, CAVS Extension)

Scope: Focus primarily on the traditional business of embedded electronics which are the products that manufacturing is currently supporting. Other nontraditional business units were not included.

Client Participants

Manager of Operations
Manager of Process Engineering
VP of Marketing
Chief Technology Officer
Materials Manager
VP of Operations

Products: Embedded Electronics
Printed Circuit Boards (PCB)
Systems

Markets
Telecom
Military
Small Opportunities

Employees
160 employees
50 hourly
110 Professional and nonexempt

Figure 4.4 Overview of Client Alpha

4.2.2 Alpha Evaluation

The following discussion provides justification for the firm's placement within each of the major attributes within the MET. The MET serves as a basis for the assessment team to discover the interrelationships and dynamics within the company. Recall, these elements were defined based upon the body of literature relating practices and factors to aspects of performance. Supporting information across each of the 55 sub-elements was carefully noted. These notes were then summarized into the following narrative across each of the 10 major taxons. The last step of the evaluation stage included the identification and prioritization of undesirable effects (UDEs) .

4.2.2.1 Business Environment (1.0) :

In summary, the markets that Alpha operates within are unpredictable and highly competitive. External threats are emerging both from customers and overseas competition. Also, Alpha operates in markets that require relatively low levels of regulation and little to no seasonality in demand.

Unpredictability is evidenced by the dramatic impact the telecommunications "bust of 2001." The majority of the client's manufacturing volume prior to the "telecomm bust" was in systems products, but "systems" now represent only 25% of their business. Presently, the majority of their volume is in components (i.e., PCB). However, components generate significantly less margin than the system products.

Their largest customers are both an opportunity and a threat. As result of the drop in the telecommunications market, their large customers began in-sourcing much of the business that was historically performed within the supply chain. This resulted in a substantial drop in Alpha's "systems" business. It appears as if opportunities within systems products, as traditionally defined, will not return to previous levels within the foreseeable future.

Emerging oversees threats are starting to be noticed, as evidenced by core equipment vendors selling into the Pacific Rim. Oversees competition has already begun to impact some of the more price sensitive aspects of their markets. Since Alpha deals with a highly technical product, they face technological risks arising from greater complexity, shortening life-times, and rapid obsolescence. Another element of risk stems from the fact that they are a small company and therefore face the risk of the departure of key employees. Perhaps their greatest threat is the presence of very large players, which are in many cases customers, forcing standardization and commoditization. If this strategy of commoditization is successful, then Alpha's ability to compete relative to customized solutions is seriously diminished. .

The size of their current market has stabilized after five years of a decline. They are aggressively working on developing other product platforms outside the telecommunications industry in order to find high growth potential. These efforts were noted during the assessment, but none of these products have matured sufficiently to warrant manufacturing involvement. Therefore they were considered outside the scope for the assessment. The figure below characterizes Alpha's business environment has assessed by the team.

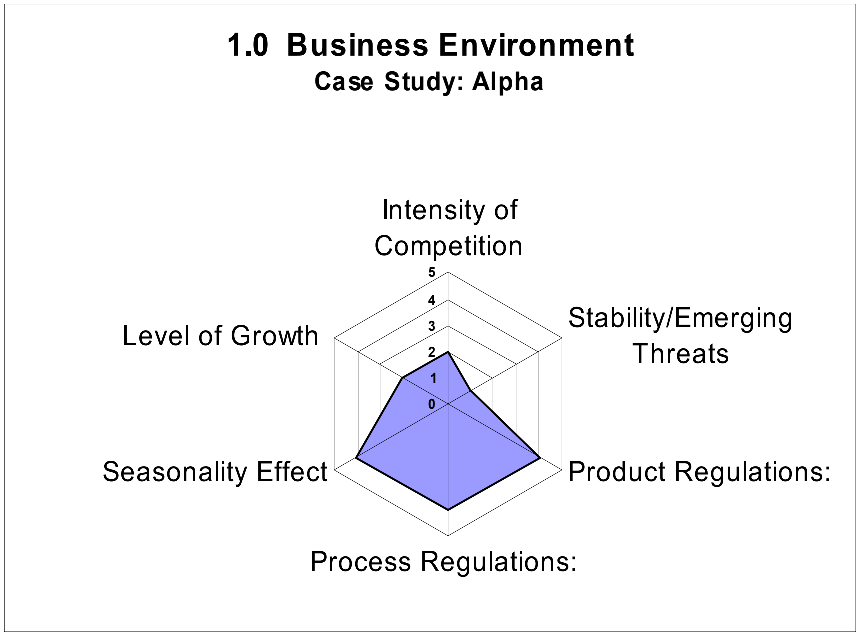

Figure 4.5 Case Alpha – 1.0 Business Environment

4.2.2.2 Leadership (2.0):

The scope of this assessment was limited to manufacturing supported business outcomes. It was noted earlier that Alpha has made considerable strategic investments in new product platforms.

Senior management clearly expressed the overall strategy was "to pursue intellectual property based products that are niche, non-commodity with custom applications." The investments in new product platforms are focused on longer term higher growth opportunities. It is believed that traditional product offerings are generally occurring within shrinking markets. The challenge Alpha faces is to transition to new product platforms, which are still early in their development cycle. It is speculated that the tension between competing in current markets, while looking to other emerging markets as the source for substantial growth, has resulted in frustration among key managers. These managers are primarily focused within legacy business segments.

Alpha's culture provides a great deal latitude given to key professionals and managers. This perhaps stems from the company's roots as a design and engineering driven company. While empowerment at those levels appears to be quite high, the plant floor workforce have not historically been engaged in operational problem solving.

Empowerment effectiveness has been hampered by the lack of an effective team approach. Individual accomplishments are acknowledged and rewarded, but no example could be cited of significant improvements in operational results achieved via cross functional teamwork. The positives typically associated with a participative culture appear to be stunted by a lack of effectiveness and discipline in accomplishing results across functions. It appears as if certain measures are owned by certain functions (e.g., manufacturing own on-time shipments). This despite the fact that cross cutting performance in terms of on-time shipping and quality are almost always the collective result of all functions within the value chain.

The figure below characterizes Alpha in terms of the Leadership attribute.

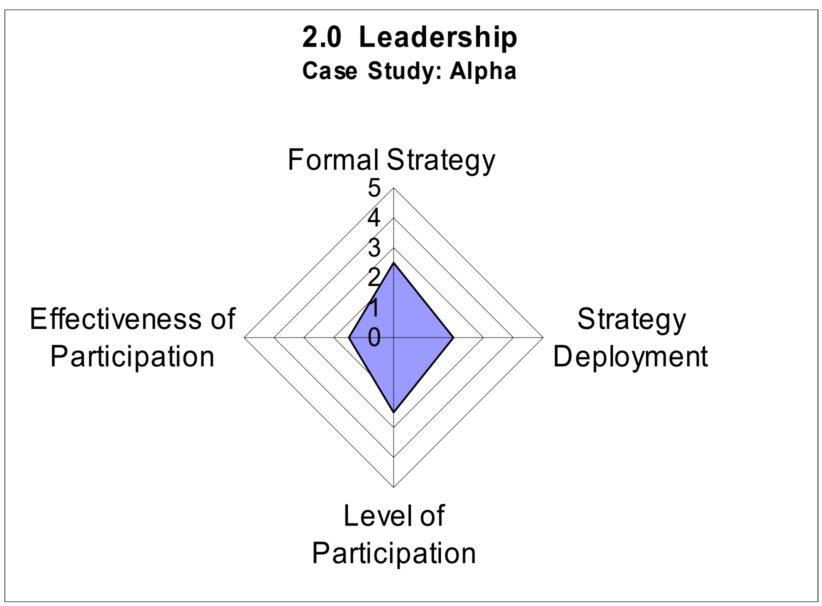

Figure 4.6 Case Alpha – 2.0 Leadership

4.2.2.3 Customer/ Market Focus (3.0):

Alpha's ability to rapidly translate customer requirements into initial prototype products was viewed as a strength. The translation from prototyping into initial production runs was viewed as effective from the perspective of the customer. There does appear to be relatively strong sense of the dimensions of performance the customers care the most about (e.g., speed and flexibility). Also there is significant opportunity to improve how various functions cooperate in order to enhance customer value.

Manufacturing volume is characterized by a "low volume, high mix" demand profile. In general, three types of products are offered from the perspective of manufacturing. These are listed as follows.

- Standard products
- Standard products with customized modifications
- New product development.

The routine production of standard products has better margins than new offerings. However, they are at risk due to obsolescence. Standard products with modification appear as a source of advantage within current markets. However, it is very clear that a core competency for the company is its ability to respond rapidly to customer needs particularly as compared to competitors. Alpha's ability to deliver physical proto-types with high levels of quality/reliability quicker than the competition is seen as a positive differentiator.

Early in the product life-cycle the emphasis is on product functionality and rapid response to customer requests. As the product moves into a more mature condition, typical operational measures tend to dominate (e.g., on-time shipment percentage, DPMO, turn around times for repairs). In their markets, quality and delivery of standard products are not "positive" differentiators, but requirements. Poor performance on these parameters can be a large negative.

Their ability to achieve responsive with a high quality and reliability has a good chance of being rewarded.

It is speculated that the customer feedback which is collected is mostly driven from the sales/design activity and is generally positive. The customer's feedback on measures more heavily influenced by manufacturing performance is not documented as clearly. However, there is a general recognition that on-time shipment percentage is running between 70-80% and repair turn-around is running 25 days against a target of 15 days. There is a general recognition that these measures are not acceptable.

The figure below illustrates Alpha's fit within the Customer/Market Focus attribute.

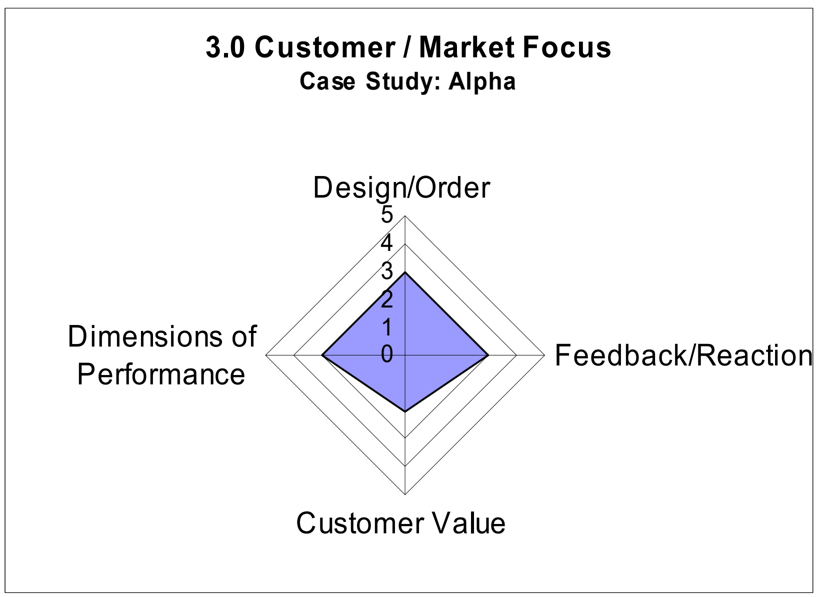

Figure 4.7 Case Alpha – 3.0 Customer / Market Focus

4.2.2.4 Information & Knowledge Management (4.0):

In general, business data and product information is available and supportive of improvement efforts. However, substantial opportunities exist in terms of working across functions to really seek out root causes and implement effective counter measures.

The data needed to support decision making is made available – typically on an "as needed" basis. It appears as if regular reporting of typical financial measures to support manager's daily decision making is limited. However, it should be noted that recently more of this type of data is shared with key managers. Monthly meetings with managers has been helpful and resulted in the routine availability of greater levels of business and financial data.

The recent implementation of a shop floor reporting system has improved substantially the data and product information needed to support production on the shop floor. This system has report writing abilities and a variety of reports about product performance is available without a lot of extra effort. However, professional level knowledge is not as well documented and tends to reside within the knowledge of particular key individuals. This is particularly a challenge in their high mix, low volume environment.

It appears as if their use of the data and information to drive effective improvements is not as effective as desired. The discipline to follow through with problem solving is difficult due to limited resources and internal focus of each function. The following illustrates the assessment of Alpha's fit within Information and Knowledge Management attribute.

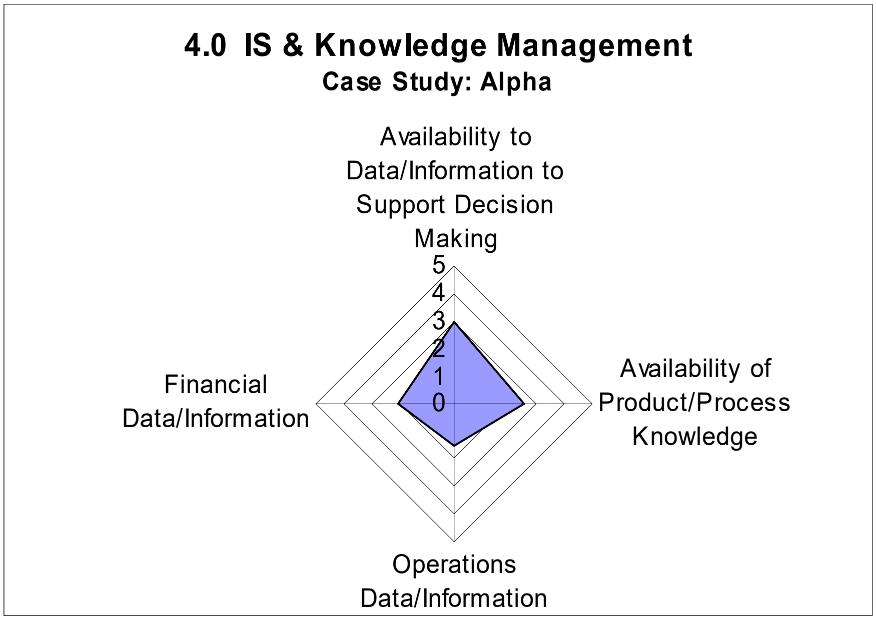

Figure 4.8 Case Alpha – 4.0 IS and Knowledge Management

4.2.2.5 Human Resources (5.0)

It appears as if individual skills dominate within the company's internal, albeit informal, reward system. Also specific the development of technical skills is strongly emphasized. The strong emphasis of developing functional/technical capabilities seems to overshadow the encouragement and rewarding of team skills and efforts. Most major successes are viewed as individual successes and not so much the results of truly effective teaming. Hourly production workers make up about 35% of the workforce; the remaining are salaried, many of which, are engineers specializing in hardware and software design. Strong culture of individual empowerment exists at the engineer/manager level. Engineers are encouraged to develop their technical skill sets and areas of expertise.

Historically shop floor employees have not been very involved in problem solving from a participative standpoint. Teaming within production has only recently begun using kaizen events. The kaizen events have been a good start to begin involving the shop floor employees in meaningfully participation. However, event scope has been modest and focused within functions within manufacturing. There is a real need to greatly develop the problem solving capacity of the shop floor employees. A tremendous opportunity exists to open the scope of events so that the kaizen events begin to target initially cross functional processes within manufacturing and later to include significant cross functional involvement outside manufacturing. In general, the empirical evidence regarding manufacturing performance suggests that the greatest business opportunities are in attacking problems and opportunities across functions. However, little evidence was seen of across the board improvements that attributable to cross functional teams working on product and operations.

The Human Resources attribute is described graphically as shown in the figure below.

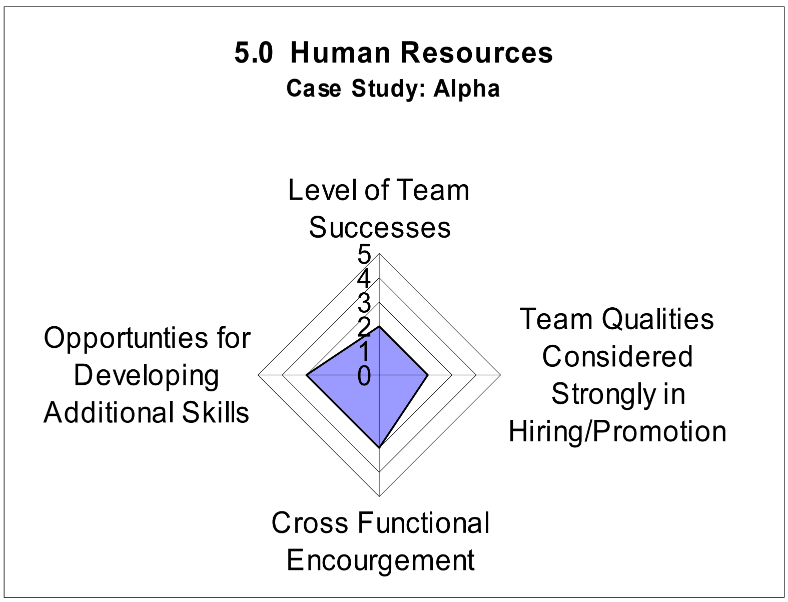

Figure 4.9 Case Alpha – 5.0 Human Resources

4.2.2.6 Development of Products and Processes (6.0):

Alpha generally views specific aspects of its development effort as a superior to its competition in terms of both lead-time and effectiveness. Process development is also important in order to maintain competitiveness. Efforts in terms of process development appear to at least be comparable to the competition.

Rapid concept through prototyping and production appears as a real strength. This is particularly true when competing with companies which are larger, but not as flexible and responsive. It appears as if new product development lead-times are “middle of the road” relative to competitors; however, their “spin-offs” on standard products is typically “better” than the competition. A complicating factor, in terms of their effort to reduce development lead-times, is the ever increasing complexity of their product (multiple increases in layers, multiple increase in points per layer, etc…).

Historically, the development of these products was viewed as an investment in internal R&D, with the hopes of converting on-going orders into production as the incumbent. However, reduced version lifetimes of these products have limited the recovery from initial R&D investment. Additional concern for these products is that large competitors have a tendency to force the industry into standardization and commoditization, which marginalizes Alpha’s ability to compete. Finally new product development requires even greater investment in R&D, more extensive prototyping and generally greater risk. Recently, there has been more effort placed on getting customers to pay for at least part of the initial R&D cycles.

It is common for product changes to continue even while initial product runs are occurring. Some of these changes may be driven internally and are therefore avoidable, while others are not. It appears as if there is a fine line between being responsive to the customer requests and the need to freeze product version in order to effectively perform initial production runs. A more formal change control process within the contract might be an opportunity. This situation points to the need for a more effective gateway that offerings must pass through before gaining entry into standard production.

The client has been averaging about 2.5 ECO's per day. It appears, from the perspective of manufacturing, that this causes considerable inefficiencies and confusion. Managing this consumes considerable management and engineering resources. In addition, regular production and prototyping are done with the same people on the same equipment as routine production. This, at times, causes confusion within production workers with respect to requirements. Often prototype requirements are not clearly defined. There does not appear to be a clear and formal gate for moving products from the prototyping stage into regular production.

It was noted during the on-site survey that, while it is desirable to reduce some of the ECO volume, there is a substantial portion of the ECOs that is directly tied to the core business strategy. Alpha attempts to differentiate itself from its competitors by focusing on quick response on customized products. Therefore, it appears as if an area of opportunity for manufacturing to better align itself with the company's basic strategy is to develop a more streamlined process for dealing with ECOs. An overall effort to reduce the standard lead-time of orders through manufacturing could be a complimentary initiative.

It appears as if a substantial improvement opportunity exists by focusing on how new products and customized standard products are transitioned into manufacturing. While a check-off list has been created, it appears as if it is either not adequate or not followed through. It was noted that from the perspective of manufacturing that final implementation of new products often lacks the required finish polish at the required level of detail. Also, it was discovered that more meaningful manufacturing/design engagement early in the design cycle is an opportunity.

The figure below characterizes Alpha's fit within the attribute Development of Products and Processes.

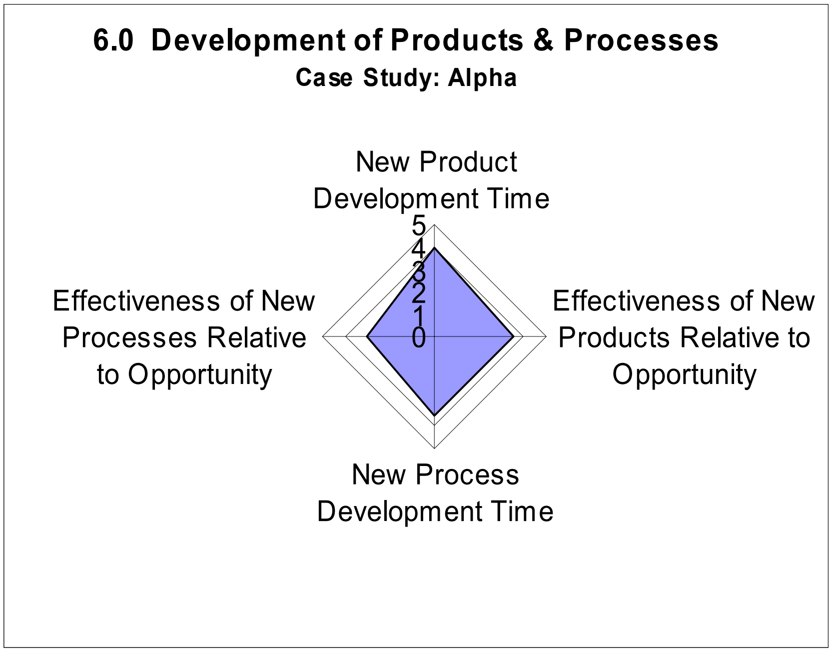

Figure 4.10 Case Alpha – 6.0 Development of Products and Processes

4.2.2.7 Product and Process Characterization (7.0):

Generally, Alpha's products once shipped have useful lifetimes of several years, however specific product versions are becoming dramatically shorter. This is a result of advances in technology and customer demand for higher levels of functionality. Product volumes are low with high levels of product variety and complexity. From a process perspective, Alpha has excess capacity (both in terms of space and two available shifts per day), highly departmentalized and functional layout. The process-product characterization is a disconnected batch line using Hayes-Wheelwright matrix, and is some characteristics of both a T and A plant using Goldratt's classification. All parts flow across some singular pieces of capital equipment. These include automated testing stations (X-ray and optical), and surface mount machine. Multiple assembly workstations were found in parallel. Work-in-process appears to be high and routine product lead-times through the plant is approximately 10 days. A "rough cut" estimate of value add process times, across all operations is 6-8 hours depending upon the job. Hot jobs are routinely expedited. The SMT process has relatively long set-up times varying from 1 to 6 hours depending upon the job. Industrial engineer's responsibilities include supervising manufacturing operations and performing typical manufacturing engineering responsibilities. All production activities occur on the first shift.

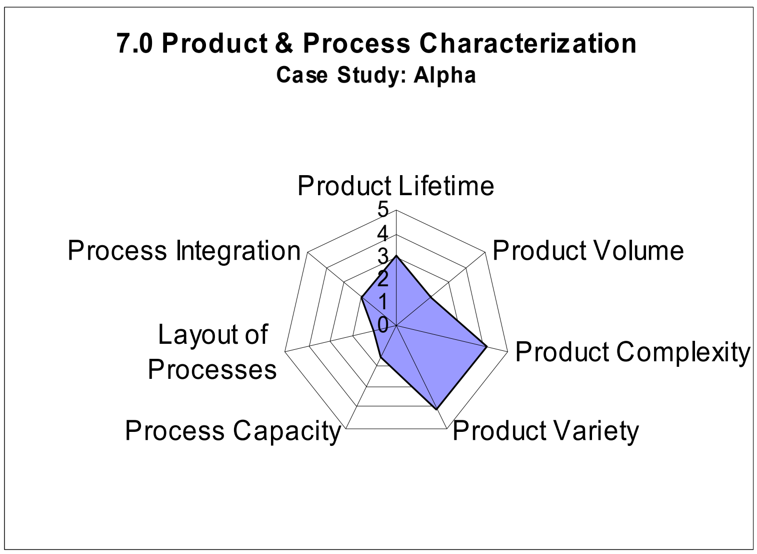

Figure 4.11 Case Alpha – 7.0 Product and Process Characterization

4.2.2.8 Management of Extended Enterprise (8.0):

Overall, product requirements to suppliers appear to be clearly communicated. For example, it is common for Alpha to issue orders for electronic components to suppliers by the supplier's part number. However, fabricated metal specifications are not as easily communicated.

Ordering and inventory requirements reflect a batch and queue push system that does not appear to be well aligned with the overall strategy of quick response and flexibility to meet customer needs. The plant is scheduled by a typical "push" work order system. The system launches orders to vendors based on offsets driven by customer due dates. Minimum order quantities are often issued above the actual customer order due, at least in part, to perceived batching requirements on the surface mount machine. The excess WIP creates a pool of products at an intermediate stage. This WIP tends to occupy prime space on the plant floor, runs the risk of being lost and cannibalized, and must be constantly managed. Also this pool makes clear visual control of orders on the plant floor difficult. Frequent expediting occurs due to customer changes. The long lead-times within the plant (i.e., 4 weeks) exacerbate this problem. This and other factors appear to relate to the company's 75% on-time shipping performance.

There does not appear to be an effective system for evaluating supplier quality performance. Repair and re-work data is not systematically correlated back to supplier performance. There is an hypothesis that a substantial barrier to improving first pass yield is supplier performance. However, due to the lack of data this hypothesis has not been tested. There is an initiative in place to at least partially address this problem. Quality specifications on electronic components are difficult to specify. Frequently, a problem with a component is not found until final test.

Since the company is a high variety low volume type of business. They do not tend to keep high levels in finished goods inventory. Most of the inventory is in the form of raw material (i.e., 280 different part numbers). Approximately 30% of the parts have vendors specified by design. Some finished goods stock is held for a few selected items which have mature and somewhat stable order patterns.

The fit of Alpha within the Management of Extended Enterprise is portrayed in the figure below.

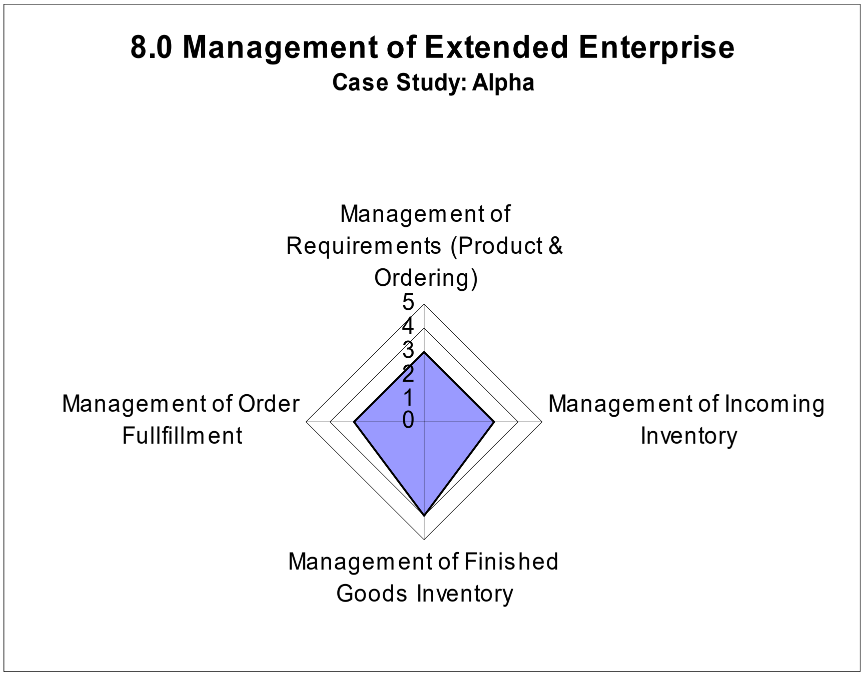

Figure 4.12 Case Alpha – 8.0 Management of Extended Enterprise

4.2.2.9 Approach to Continuous Improvement (9.0):

Numerous opportunities exist for Alpha to develop a more powerful approach to continuous improvement. This includes developing closer alignment between performance measures and company's overall strategy. Additional opportunity exists to improve process focus by reducing setup time, releasing orders to the shop based on customer demand, and dramatically reducing lead-time of orders through the plant. The enhanced use of cross functional teams to solve core operational and product problems across functional boundaries is needed. The quality system is adequate from the perspective of containing a formally defined and executed system. However, a big opportunity exists in dramatically improving the quality system effectiveness through enhanced team based problem solving.

Managing change and improvement across functional boundaries is exceptionally difficult. Design tends to have an overly simplistic understanding of the needs of manufacturing and how they are impacted. Manufacturing is more concerned about the problem of the day and has a tendency to not be proactive when it comes to engaging upfront with design. This is when the best opportunity exists to prevent later problems in production.

The company is registered to ISO 9001. However this appears to be compliance driven rather than effectiveness driven. Internal quality rates are tracked and reported. Approximately 13% of production volume must leave the line and go to repair, first pass yield at final test is running at 92%, actual non-repairable fall-out is 2-3%. These measures have either stayed constant or only modestly improved. Small incremental improvements have resulted from the implementation of new equipment (e.g., automated testing). Also some improvements have been seen on a per job basis. However, few if, any across the board substantial improvements have been made in key operational measurements.

It appears as if there is a substantial opportunity to establish reduction in plant lead-time as a new performance measure that is in alignment with the company's strategy.

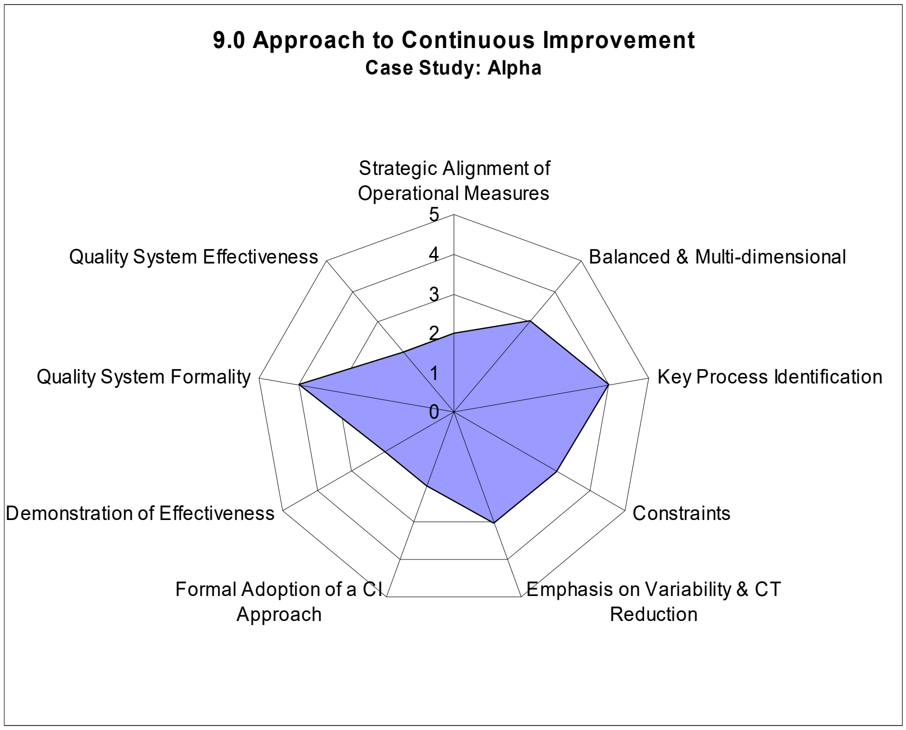

Figure 4.13 Case Alpha – 9.0 Approach to Continuous Improvement

4.2.2.10 Financial Health (10.0)

Neither the availability of capital for good investments nor cash flow appears to negatively constrain daily operations.

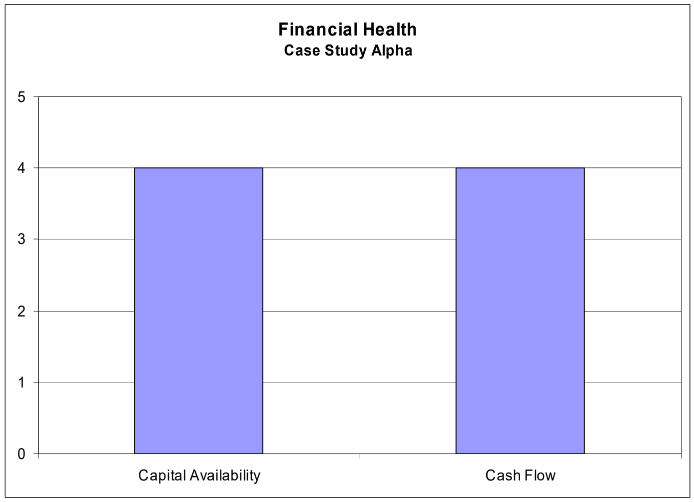

Figure 4.14 Case Alpha – 10.0 Enterprise Financial Health

4.2.2.11 Overview of Alpha's MET Fit

The following radar chart illustrates the composite score across the ten major classifications of the MET.

In general, significant challenges appear in the areas of unpredictable market with numerous threats, exhibiting stronger leadership across functions, incompatibility between a differentiated strategy and long lead-times in manufacturing, trouble with dealing with frequent product changes from an operations standpoint, and lack of a systematic method for measuring and improving supplier quality.

Strengths appear to include high level of responsiveness to customer's changing requirements, high level of individual ownership and empowerment among key managers and professionals, aggressive work on developing new and hopefully more profitable product platforms, manufacturing use of lean principles embodied through systematic use of Kaizen Events.

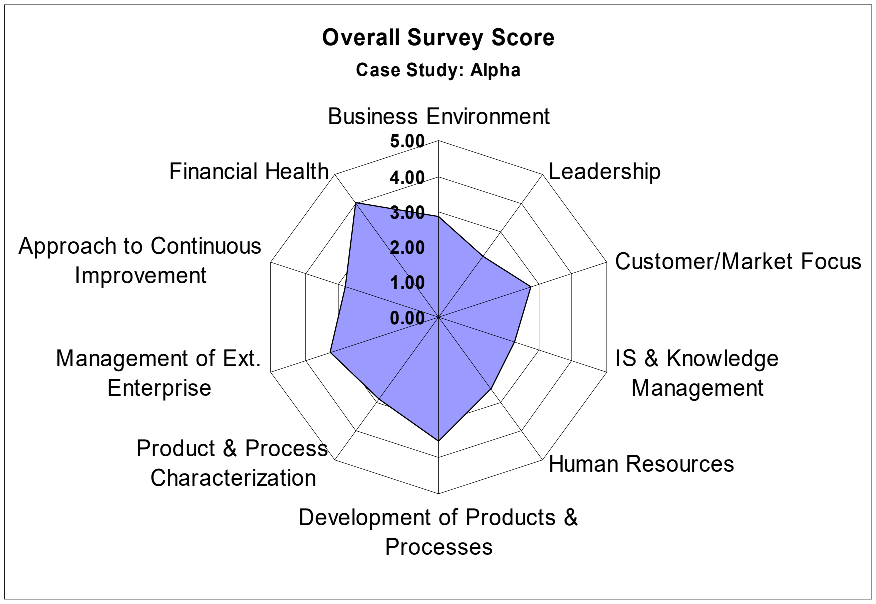

Figure 4.15 Case Alpha – Overall Fit within MET

Therefore, the client "Alpha" classified at the time of this assessment within the Manufacturing Enterprise Taxonomy (MET) as follows.

Category	Sub-category	Item	Score	Average for Category	Average for Taxon
1.0 Business Environment					
	1.1 Competitive Environment	1.1.1 Intensity of Competition	*2*	1.50	2.83
		1.2.1 Stability/Emerging Threats	*1*		
	1.2 Regulatory Environment	1.2.1 Product Regulations:	*4*	4.00	
		1.2.2 Process Regulations:	*4*		
	1.3 Market Conditions	1.3.1 Seasonality Effect	*4*	3.00	
		1.3.2 Level of Growth	*2*		
2.0 Leadership					
	2.1 Strategic Planning & Deployment	2.1.1 Formal Strategy	*2.5*	2.25	2.13
		2.1.2 Strategy Deployment	*2*		
	2.2 Culture of Empowerment	2.2.1 Level of Participation	*2.5*	2.00	
		2.2.2 Effectiveness of Participation	*1.5*		
3.0 Customer / Market Focus					
	3.1 Translation of Requirements	3.1.1 Design/Order	*3*	3.00	2.75
		3.1.2 Feedback/Reaction	*3*		
	3.2 Positioning / Value	3.2.1 Customer Value	*2*	2.50	
		3.2.2 Dimensions of Performance	*3*		
4.0 Information System & Knowledge Management					
	4.1 Access to Information & Knowledge	4.1.1 Availability to Data/Information to Support Decision Making	*3*	2.75	2.25
		4.1.2 Availability of Product/Process Knowledge	*2.5*		
	4.2 Supportive of Improvement Efforts	4.2.1 Operations Data/Information	*1.5*	1.75	
		4.2.2 Financial Data/Information	*2*		
5.0 Human Resources					
	5.1 Maturity in Teaming	5.1.1 Level of Team Successes	*2*	2.00	2.50
		5.1.2 Team Qualities Considered Strongly in Hiring/Promotion	*2*		
	5.2 Employee Skill Level	5.2.1 Cross Functional Encouragement	*3*	3.00	
		5.2.2 Opportunities for Developing Additional Skills	*3*		
6.0 Development of Products & Processes					
	6.1 Product Development	6.1.1 New Product Development Time	*4*	3.75	3.50
		6.1.2 Effectiveness of New Products Relative to Opportunity	*3.5*		
	6.2 Process Development	6.2.1 New Process Development Time	*3.5*	3.25	
		6.2.2 Effectiveness of New Processes Relative to Opportunity	*3*		
7.0 Product & Process Characterization					
	7.1 Product Characterization	7.1.1 Product Lifetime	*3*	3.25	2.83
		7.1.2 Product Volume	*2*		
		7.1.3 Product Complexity	*4*		
		7.1.4 Product Variety	*4*		
	7.2 Process Characterization	7.2.1 Process Capacity	*1.5*	1.50	
		7.2.2 Layout of Processes	*1*		
		7.2.3 Process Integration	*2*		
	7.3 Product-Process Characterization	7.3.1 Goldratt's VAT Logical Product-Process	*4*	4.00	
		7.3.2 Hayes-Wheelwright Matrix	*4*		
8.0 Management of Extended Enterprise					
	8.1 Supply Chain Management	8.1.1 Management of Requirements (Product & Ordering)	*3*	3.00	3.25
		8.1.2 Management of Incoming Inventory	*3*		
	8.2 Distribution Chain Management	8.2.1 Management of Finished Goods Inventory	*4*	3.50	
		8.2.2 Management of Order Fulfillment	*3*		
9.0 Approach to Continuous Improvement					
	9.1 Performance Measures	9.1.1 Strategic Alignment of Operational Measures	*2*	2.50	2.78
		9.1.2 Balanced & Multi-dimensional	*3*		
	9.2 Process Focus	9.2.1 Key Process Identification	*4*	3.33	
		9.2.2 Constraints	*3*		
		9.2.3 Emphasis on Variability & CT Reduction	*3*		
	9.3 Use of Specific World Class Practices	9.3.1 Formal Adoption of a CI Approach	*2*	2.00	
		9.3.2 Demonstration of Effectiveness	*2*		
	9.4 Quality System	9.4.1 Formal System	*4*	3.00	
		9.4.2 Demonstration of Effectiveness	*2*		
10.0 Enterprise Financial Health					
	10.1 Capital Availability	10.1.1 Capital Availability	*4*	4.00	4.00
	10.2 Liquidity	10.2.1 Cash Flow	*4*	4.00	

Figure 4.16 Case Alpha – Detail Fit within the MET

The outcome of the Evaluation phase in addition to the client's "fit" within the MET is the identification of Undesirable Effects (UDEs). As the following figure illustrates, a total of 16 UDEs were identified during the survey. The UDEs were prioritized through a multi-voting process conducted with participants from Alpha. The scores associated with each UDE are shown below.

Prioritization of UDEs Identified During the MET Survey			Case: Alpha
	UDE	Overall	Cummulative Percentage
1	***Not a clearly defined and embraced strategy for how manufacturing should best support sustained advantage.***	***50***	***25%***
2	***Multiple changes (e.g., product configuration and changes in design) which result in chaos in manufacturing.***	***35***	***43%***
3	***Percentage of On-Time shipments is running @ 75% (below customer expectation)***	***25***	***55%***
4	Lack of communication between manufacturing and design	15	63%
5	Hourly workers do not feel like they are respected/listened to … Mismatch between hourly employee needs and level of direction provided.	15	70%
6	Data collection to support a reliable measurement of the quality of supplied product.	15	78%
7	Changeovers (e.g., SMT) take too long	15	85%
8	Difficulty to getting root causes solutions on problem areas pointed at by the data.	10	90%
9	Turn around on repairs not meeting internal objective	5	93%
10	Takes too long to get a built prototype	5	95%
11	Protoypes have too many bugs	5	98%
12	Manufacturing concerns are not uncovered early in the prototype phase.	5	100%
13	Difficulty on recognizing (confusion) the difference between prototyping and production expectations at the shop floor.	0	100%
14	Current process for supporting ECOs and spins are more costly than we would like.	0	100%
15	Expediting of customer orders is common.	0	100%
16	"Pool" in manufacturing (not voted)	0	100%
	Total	200	

Figure 4.17 Case Alpha – UDE Prioritization

The TBAM approach calls for the top three UDEs to serve as inputs into the diagnosis phase. These UDEs are used in constructing the client's Current Reality Tree (CRT). The selected UDEs are shown and labeled in the figure below.

Highest Priority UDEs for Use in CRT Construction	
UDE-1	***Not a clearly defined and embraced strategy for how manufacturing should best support sustained advantage.***
UDE-2	***Multiple changes (e.g., product configuration and changes in design) which result in chaos in manufacturing.***
UDE-3	***Percentage of On-Time shipments is running @ 75% (below customer expectation)***

Figure 4.18 Case Alpha – Top Three UDEs for Use within CRT

4.2.3 Alpha Diagnosis

The purpose of the diagnosis stage is to develop a logical linkage between the UDEs (i.e., symptoms) and a relatively small set of root causes. This is accomplished by the construction of the Current Reality Tree (CRT).

The CRT was constructed by picking one of the three previously identified UDEs and probing the next level of causes. Those causes are then treated as effects driven by a lower level of causes. This procedure is repeated until a large number of the UDEs appear to be related to a relatively few number of root causes.

The three CRT selected for use as input into the construction of the CRT are listed and labeled below.

- UDE-1: Not a clearly defined and embraced strategy for how manufacturing should support a sustained advantage
- UDE-2: Multiple changes (e.g., product configuration and changes in design) result in chaos within manufacturing.
- UDE-3: Percentage on-time shipments is running at 75% which is below customer expectations

These UDEs were reviewed and UDE-3 was selected for initial probing by the assessment team because it was believed that the assessment team initially possessed a higher level of intuition about this UDE than the other two. However, the ultimate goal is to drive down from all selected UDEs into a limited set of root causes.

Explanation of UDE-3

The logic of the CRT is somewhat tedious. The tree is constructed by selecting a UDE and drilling down to what causes give rise to that effect. The cause and effect relationships are indicated by a connecting arrow. The case of a AND condition is indicated by a bold elliptical line crossing multiple arrows. For example, UDE-3 is driven by the sets of following causes as illustrated in CRT Figure #1.

- If "quality problems occur (100)" and if "time to respond takes longer than the time available" then "frequently customer due dates are missed (UDE-3)."
- If "product changes occur" and if "product changes require lots of time and resources (200)" and if "time to respond takes longer than time available" then "frequently customer due dates are missed (UDE-3)."

In order to get a sense of how the tree operates other key intermediate effects are analyzed. The effect "insufficient time available to respond (300)" is explained as follows based on the CRT Figure #2.

- "If long lead-time is needed for production" then "insufficient time is available to respond (300)."
- If "prototypes drop in unexpectedly" and if "prototypes compete with regular production resources" then "insufficient time is available to respond (300)."

Next the effect, "long lead-time needed for production" is traced through a set cascading of singular causes results as follows.

- "If the plant is managed along functional lines and not flow lines (340)" then "changeovers are too long."
- If "changeovers are to long" then ultimately "WIP levels are too high."
- If "WIP levels are too high" then "long lead-time needed for production."

Finally the effect "plant is managed along functional lines and not flow lines (340)" is illustrated in the CRT Figure #3. This effect (#340) is driven ultimately by the following two roots: "perception is that additional capital equipment is required to achieve flexibility (RT-2)" and "process knowledge is best gained by focusing on each process step individually (RT-3)."

Based on the first CRT figure another chain of cause and effect relationships explain the root UDE-3. This chain leads to the entity "each function is managed independently (400)" which is found ultimately at the bottom of the first CRT figure. This entity shows up at other places on the CRT but is "exploded" on the CRT figure #6. Ultimately the root of entity #400 is "lack of a clear understanding of the value chain resulting in key business outcomes - prototyping, ECOs, and standard production (RT-1)."

Explanation of UDE-2

The CRT figure #5 illustrates the connection of the UDE-2 to the intermediate effect "each function is managed independently (400)." The root of entity #400 is found on the CRT Figure 6. This root is "lack of a clear understanding of the value chain resulting in key business outcomes – prototyping, ECO, and standard (RT-1)".

Explanation of UDE-1

The CRT figure #6 also illustrates that RT-1 is the direct root of UDE-1.

Summary of the CRT Analysis

The root "lack of a clear understanding of the value chain resulting in key business outcomes – prototyping, ECO, and standard (RT-1)" is the full root of UDE-2 and UDE-1 and is a partial root of UDE-3. Thus, RT-1 helps explain all the selected UDEs from the evaluation phase. The intermediate effect "each function is managed independently (400)" was found to be integral to both UDE-2 and UDE-3.

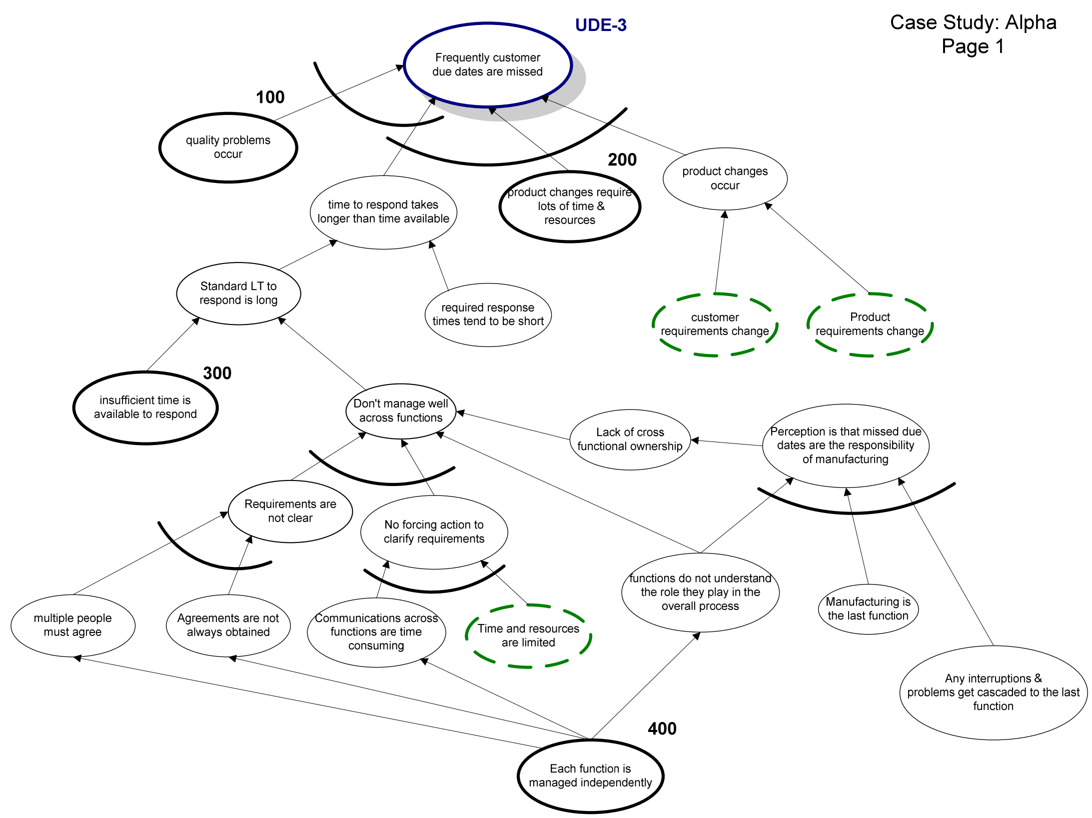

Figure 4.19 Case Alpha – CRT page 1

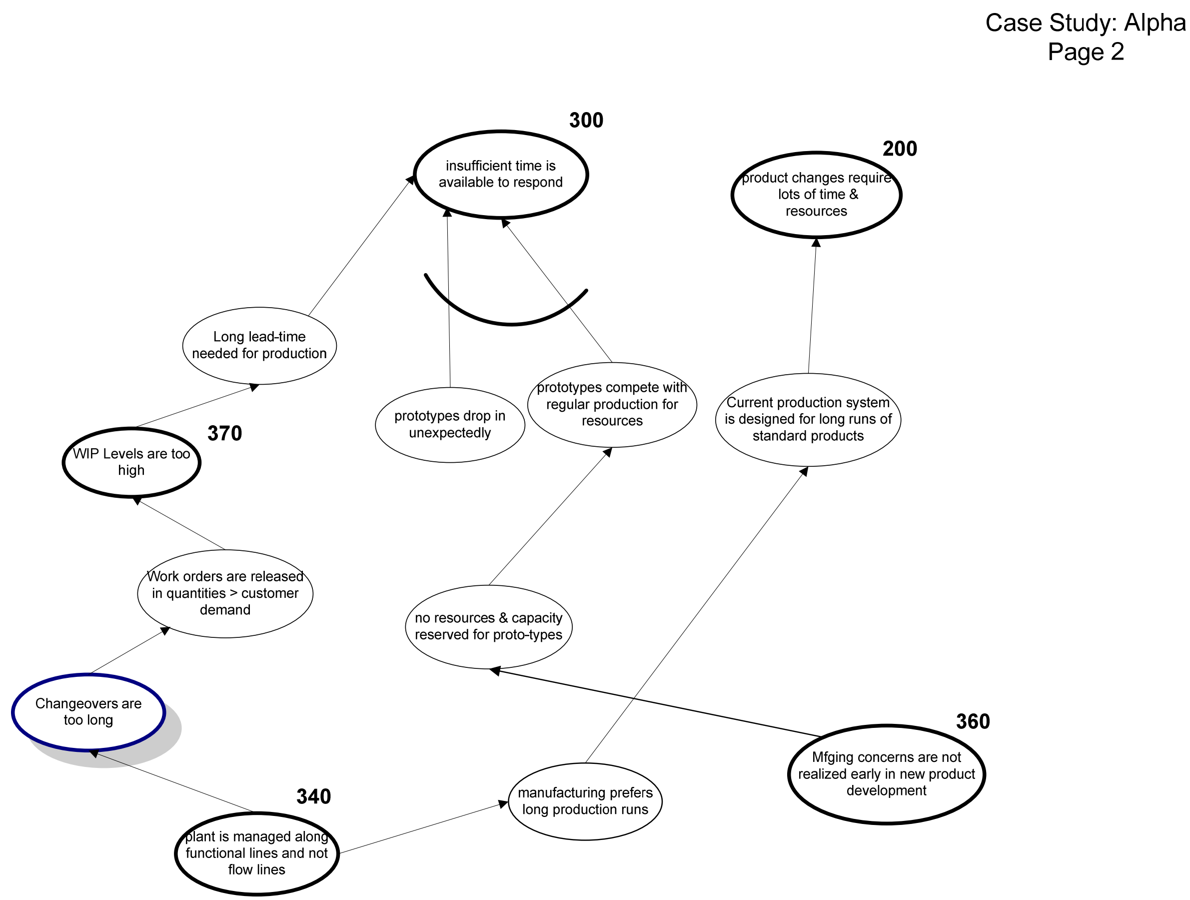

Figure 4.20 Case Alpha – CRT page 2

Case Study: Alpha
Page 3

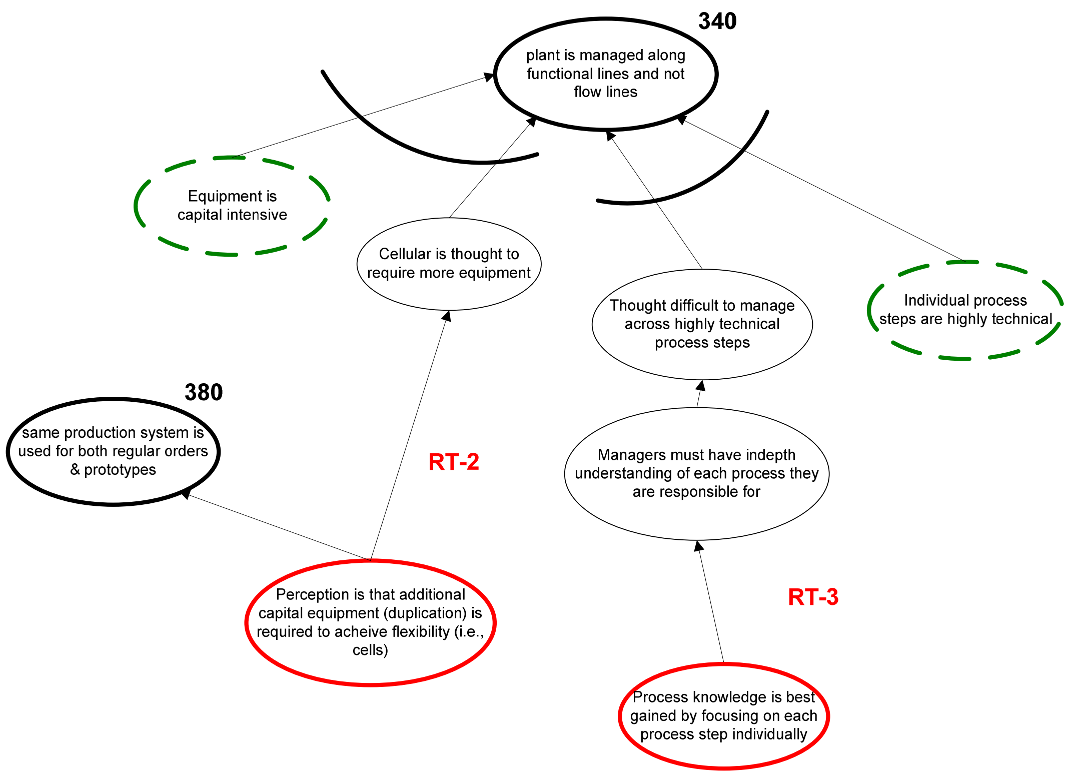

Figure 4.21 Case Alpha – CRT page 3

Case Study: Alpha
Page 4

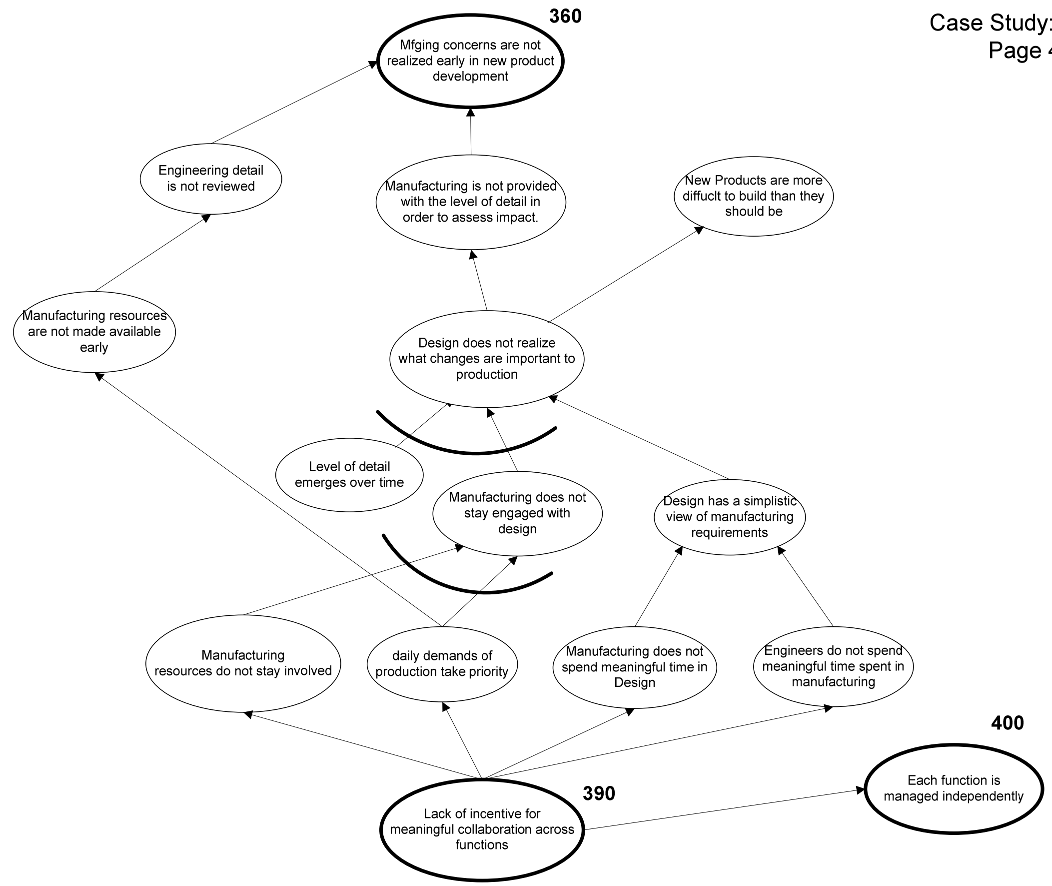

Figure 4.22 Case Alpha – CRT page 4

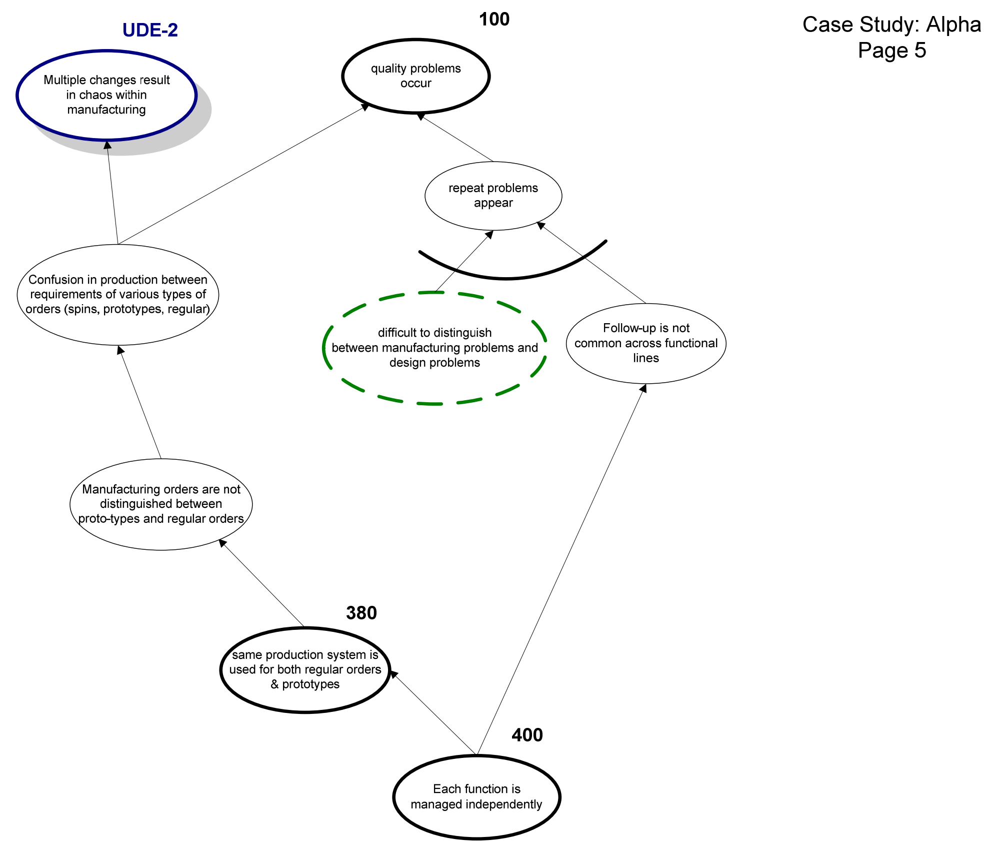

Figure 4.23 Case Alpha – CRT page 5

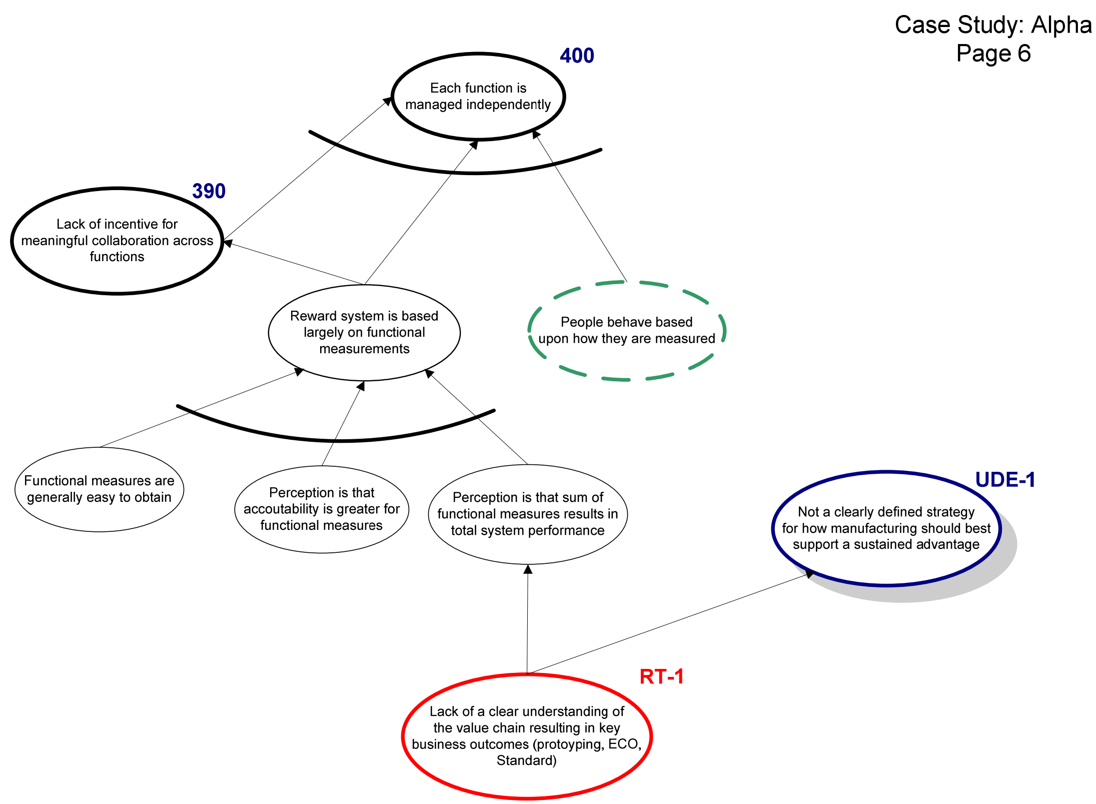

Figure 4.24 Case Alpha – CRT page 6

The following table summarizes the results from the application of the CRT. Notice that there is not a one-to-one correspondence between the three UDEs and the three roots. Their relationships stem from the construction of the CRT. The CRT, illustrates the logical relationship, as established by the assessment team in collaboration with the SMR from the client, connecting the UDEs with root causes. It is purely a coincidence that this tree resulted in having three roots. The goal of the CRT analysis is to reduce the number of root causes if possible to a single root cause. However, this is not always possible given the time and resources available to develop the tree.[163]

UDEs	Root Causes
• **UDE-1:** Not a clearly defined and embraced strategy for how manufacturing should best support a sustained advantage.	• **RT-1:** Lack of clear visibility of the value chain of activities required to support key business outcomes.
• **UDE-2 :** Multiple changes (e.g., changes in product design and changes in design) result in chaos within manufacturing.	• **RT-2:** Perception is that additional capital equipment is needed to achieve the desired flexibility (i.e., cells)
• **UDE-3:** Percentage of on-time shipments is running @ 75% which is below customer expectations	• **RT-3:** Process knowledge is best gained by focusing on each step individually.

Note: The precise relationship between UDEs and Root Causes is defined within the CRT.

Figure 4.25 Case Alpha - Summary of UDEs and Root Causes

4.2.4 Alpha Prescription

The purpose of the prescription stage is to develop a set of recommendations targeted at elimination of the root causes (i.e., RT-1, RT-2, RT-3) identified as a result of the diagnosis stage.

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[163] For more discussion on this see pg. 74 of the text written by H. William Dettmer titled "Goldratt's Theory of Constraints", ASQ Quality Press, 1997, Milwaukee, Wisconsin.

The first step is to identify which of the 91 practices from the PST, are most relevant for use as guidelines in the development of specific recommendations.

This was accomplished by the assessment team multi-voting. In the case of Alpha, the multi-voting was for the entire case and not separately for each of the root causes. The other cases used a multi-voting approach that was more focused on each individual root from the CRT. These total scores from the multi-vote are shown in the Figure below. The rule of thumb is to select subset of prescriptions that account for approximately 80% of the total score. In the case of Alpha, this procedure resulted in identifying a subset of 11 out of the total 91 PST elements. In general, these are the most relevant set of best practices used to guide the development of the set of recommendations. The result of this process is summarized in the Figure below.

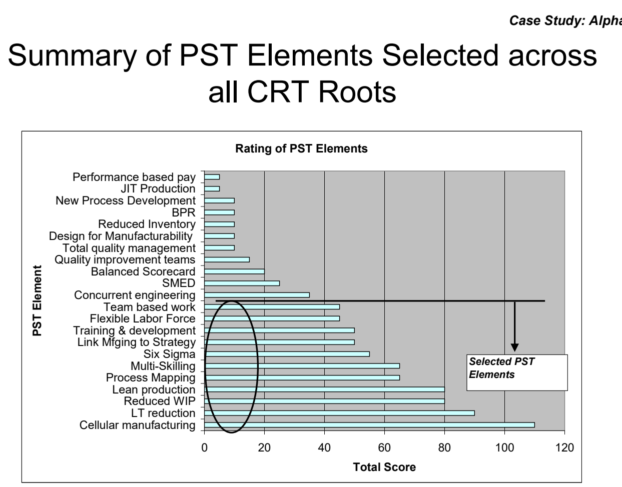


Figure 4.26   Case Alpha – PST Elements Scored across all CRT Roots

The context for the recommendations was established through following set of root causes from the CRT.

- “lack of a clear understanding of the value chain resulting in key business outcomes (e.g., prototyping, ECOs, and standard production).
- “ perception is that additional capital equipment is required to achieve cellular flexibility” (RT-2)
- “process knowledge is best gained by focusing on each process step individually” (RT-3)

The rule of thumb is to select the PST elements that represent 80% of the total scores. In the case of Alpha, this procedure resulted in identifying 11 out of the 95 PST elements for use during the development of specific recommendations. These elements are highlighted in bold in the Table below. This selection process resulted in the following “best practice” elements from the PST to be used as guidelines in the development of the recommendations.

- 3.C-3 Cellular manufacturing
- 1.C-4 LT reduction
- 1.B-1 Reduced WIP
- 4.B-1 Lean Production
- 1.B-3 Process Mapping
- 1.E-2 Multi-skilling
- 4.D-5 Six Sigma
- 4.B-7 Link manufacturing to strategy
- 1.E-5 Training and development
- 3.B-4 Flexible labor force
- 3.E-2 Team based work.

The following recommendations were formulated to attack the root causes.

Recommendation #1: Develop a value stream map for the ECO and prototyping cross functional business processes. Reengineer the processes both inside and outside manufacturing so that the company is enabled to handle changes seamlessly and rapidly. Establish 50% lead-time reduction as the major performance measure for guiding improvements enabled through improved concurrency between manufacturing and design. Establish lead-time as the bride between manufacturing performance and overall company strategy.

Recommendation #2: Create separate focus in manufacturing so that regular production and prototypes are not mixed. This may occur either by physical segregation (i.e., clustering equipment and/or workstations) or separation by time (i.e., shift dedication). Given the demand swings between type of product this will involve more aggressive cross functional training of people.

Recommendation #3: Establish cross functional management within manufacturing. Leading performance measures are to reduce manufacturing lead-time and WIP by 50%. Key enablers appear to be reducing set-up time on the SMT, reducing the size of released orders, and re-arrange equipment on the floor to facilitate flow.

The following Figure illustrates how the selections from the PST are referenced within the stated recommendations.

Case Study: Alpha

Linking PST Elements to Recommendations

Recommendations

- **Rec_1:** Develop a value stream map for the ECO and prototyping cross functional business processes **(1.B-3).** Reengineer the processes both inside and outside manufacturing so that the company is enabled to handle the changes seamlessly and rapidly **(4.B-1)**. Establish 50% reduction in LT as the major performance measure for guiding improvements **(1.C-4)**. Establish LT as the bridge between manufacturing performance and strategy **(4.B-7)**.
- **Rec_2:** Create separate focus in manufacturing so that regular production and prototypes are not mixed **(3.C-3)** . This may occur due to either physical segregation (i.e., clustering equipment and or workstations) or by time (i.e., shifts). Given the level of demand swings, this should include more aggressive cross training of people **(1.E-2)**.
- **Rec_3:** Establish cross functional management within manufacturing **(3.C-3)** . Leading performance measures are to reduce by 50% LT reduction and WIP **(1.B-1)** . Key enablers **(4.B-1)** appear to be reducing the set-up time on the SMT **(1.C-6)** , size of order releases, and re-arrange equipment to facilitate flow **(3.C-3)**.

Prioritized PST Elements Across all Roots

Ref #	*PST Element*
3.C-3	Cellular manufacturing
1.C-4	LT reduction
1.B-1	Reduced WIP
4.B-1	Lean production
1.B-3	Process Mapping
1.E-2	Multi-Skilling
4.D-5	Six Sigma
4.B-7	Link Mfging to Strategy
1.E-5	Training & development
3.B-4	Flexible Labor Force
3.E-2	Team based work

Figure 4.27 Case Alpha – Linking PST Elements to Recommendations

A summary of the translation of Alpha's undesirable effects into recommendations is illustrates in the figure below.

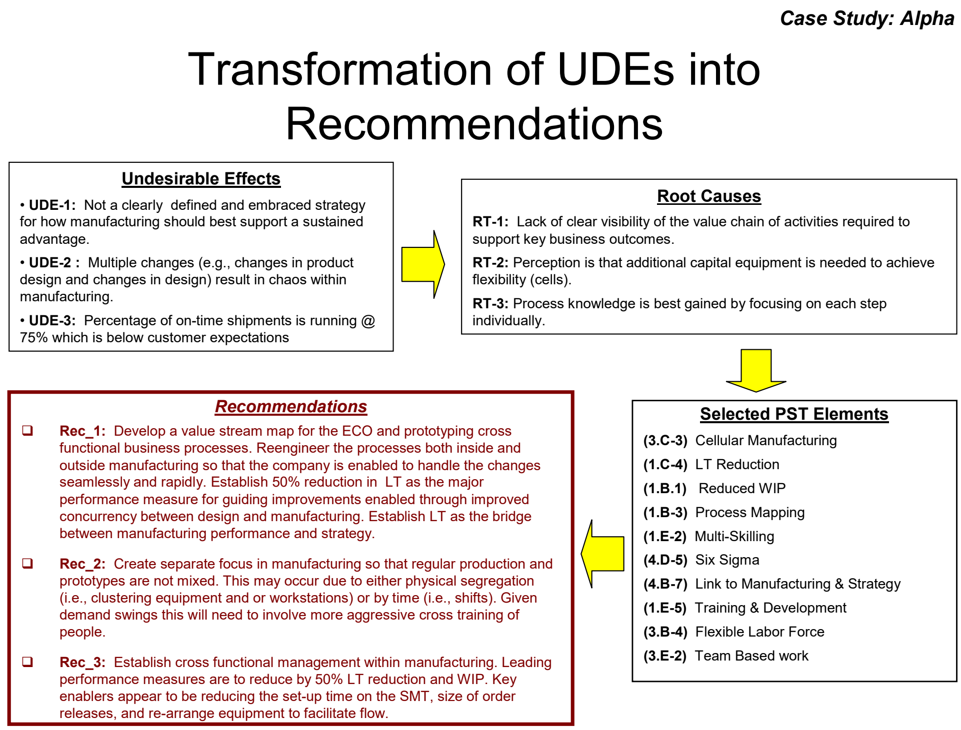


Figure 4.28 Case Alpha – Transformation of UDEs into Recommendations

4.2.5 Client Receptivity

The client's feedback to the overall methodology and to resulting recommendations is summarized in the following Figure. The client's SMR rated each recommendation on a scale of one (strong disagreement) to five (strong agreement) in terms of both effectiveness and implementability. In general, the client was particularly supportive of recommendations #2 and #3 in terms of their effectiveness and implementability.

TBAM Feedback: Client Receptivity

Recommendation	Effectiveness "The recommendation, if implemented, would have a substantially positive impact on the manufactring enterprise." Please rate each recommendation on a score of 1-5 Score 1: Strongly Disagree Score 5: Strongly Agree	Implementability "The recommendation is practical and implementable without spending excessive time and resources." Please rate each recommendation on a score of 1-5 Score 1: Strongly Disagree Score 5: Strongly Agree	Overall Score
Rec_1:	4.5	3.5	8
Rec_2:	3	2	5
Rec_3:	5	4	9

General Comments
The process forces logical thinking about big picture issues. These issues tend to have an emotional context which the logical process alleviates. It also serves as a good guidelines for objective discussion. This discussion process has a way of breaking some of the barriers to solving problems being assessed.
Although the process was more time consuming than expected, the result was worth it. It was definitely a learning experience. I regret that we could not be a part of each piece fully but it was understandable based upon the time constraints.

Figure 4.29 Case Alpha – Client Feedback

4.3 Case Study #2: Beta

The entire case study is found in the appendix, the purpose of this section is to illustrate the TBAM approach by providing a summary of findings during the case study across each of the three stages (Evaluation - Diagnosis- Prescription).

4.3.1 Introduction to Beta

Beta is a one of several manufacturing sites for a publicly owned parent company. The parent company sales volume is approximately $150 million. The Beta plant operates essentially as a focused business unit and virtually all of the business functions are located on-site. The onsite employment level is 100 employees, which are split evenly between production and the office. The Beta site produces an annual sales volume of approximately $25 million.

Beta produces electrical bus systems that are installed at power plant sites around the world. Most of Beta's business is domestic sales; however, international sales have recently become more significant. This business is cyclical and driven primarily by the construction and major modifications of power plants. Due to each job sites unique requirements (e.g., obstructions, amperage, …) each order is custom engineered. Three basic product lines are offered: isolated phase bus (IPB), rectangular segregated, and rectangular non-segregated. The Figure 4.30 serves as an introduction to this case study.

4.3.2 Beta Evaluation

The on-site survey was conducted across a 1.5 day period by two assessors. The assessment team spent 1 day comparing notes and developing the final scoring for completing the assessed fit within the MET. The next working day the client was contacted for feedback and validation of Beta's fit within the MET.

Case Study Beta
August 2-3, 2007

Assessors: Clay Walden, Steve Puryear (Mississippi State University, CAVS Extension)

Scope: Focus on the on-site assessment of core functions which support the product manufacturing. On site functions include Human Resources, Accounting, Design, Project Management, Quality, Service, Manufacturing, Purchasing, and Planning.

Client Participants
Plant Manager
HR Manager
Engineering Manager
Quality and Service Manager
Planner
Purchaser
Controller

Products: Power Plant Bus System
Isolated Phase Bus
Rectangular Segregated
Rectangular Non-Segregated

Markets
Sell to Engineering and Contracting Firms
End users are large power plants.

Employees
100 employees
50 Hourly
50 Office

Figure 4.30 Overview of Client Beta

4.3.2.1 Business Environment (1.0):

The business environment that Beta operates within is characterized by a moderate level of competition, cyclic though not seasonal demand, no major external threats, and a relatively low level of regulation. Beta, as well as its industry, is currently experiencing a strong rate of growth.

The number of competitors Beta faces depends upon the product line. Beta's volume is driven approximately equal from its three major products. For the isolated phase bus (IPB) product line, Beta and one other company have captured almost all of the market. In the case of their rectangular-segregated product, they have become virtually a sole source to one large customer. Finally, numerous competitors offer competing products within their market for rectangular-non-segregated product market.

There were some external threats identified, but none appear to cause much concern. The technical threat consists primarily of the development of other product types (e.g., cable buss systems) to replace their products. The chances of this threat emerging appeared somewhat remote at the time of the assessment. Another threat over time is China's explosive growth in building power plants. Therefore, Chinese products could begin entering the world markets and become a source of increased competition.

The market for the construction, expansion, and modifications of power plants tend to be cyclical. This is the overall business environment that Beta must operate within.

Presently they are growing at about 20% annually, but have weathered a downturn in their business as recently as 2005. Additional evidence of Beta's cyclical pattern was over the last several years' site employment levels have varied from 50 to 150 employees. Also, it was mentioned that the cyclical business patterns impacts influence how the company views capital investments. This will be further discussed in the enterprise financial health section of the case study.

Outside the typical types of regulations (e.g., OSHA) that virtually every manufacturer faces, little evidence was found of specific governmental regulations. However, the industry is highly dependent upon ANSI codes established from within the industry.

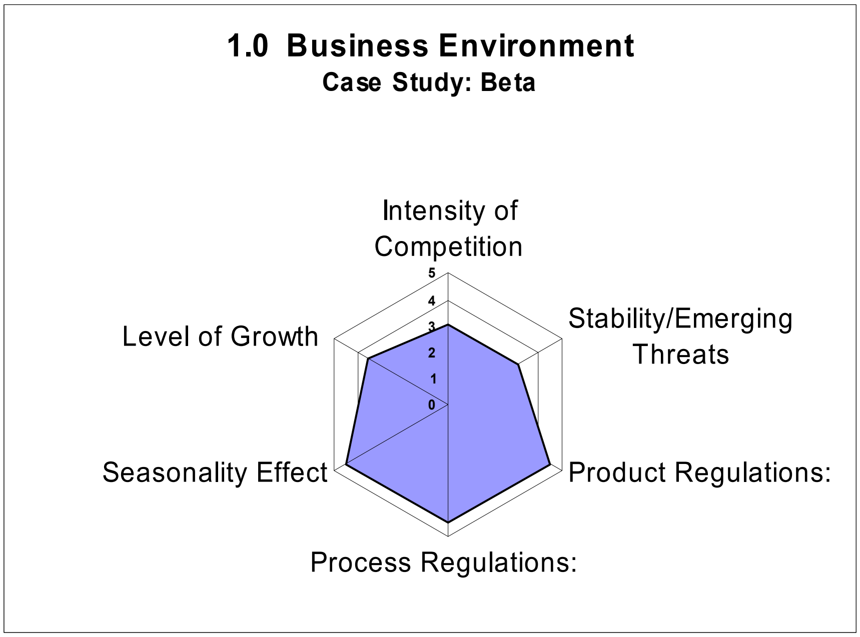


Figure 4.31 Case Beta – 1.0 Business Environment

4.3.2.2 Leadership (2.0):

Overall there is evidence that the leadership at Beta will make difficult strategic decisions, and strategy has generally been understood and actively supported by those directly involved. However, the level and effectiveness of employee empowerment depends upon within which function the employee resides.

Senior leadership has clearly established guidelines for the types of jobs they will go after in the market place. About two years ago, an intentional decision was made to compete on those jobs which fit their niche. These are the jobs which should generate strong profit margins. Therefore they appear to fit Porter's generic differentiation strategy.

One of Beta's best sources of differentiation is the additional "value add" they bring to the customer from the standpoint of superior service. Few competitors offer the full range of installation, service, and repair offerings. This has, at times, enabled Beta to be seen by their customers as a strategic partner, which has shielded them from some of the price pressures. Many cases exist, particularly in the case of the IPB business, where Beta has won the order without being the lowest cost.

Another example of strategic decision making by senior management was the initiation of their product standardization effort. This initiative resulted in consolidating many of their product offerings into standard components. This has allowed them to enhance the quality and efficiency of both design and production.

Employees that work in engineering and design appear to experience a high level of employee participation and effectiveness. However those that reside in support functions and on the shop floor have not historically experienced a high degree of involvement. The shop floor participation in 5S kaizen events, though just beginning, is an emerging example of effectively engaging the shop employees.

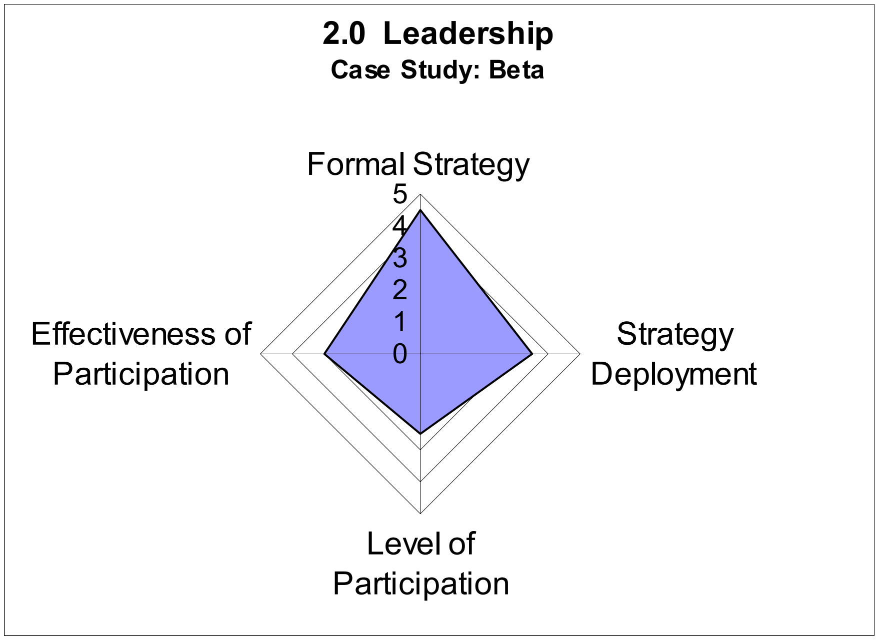


Figure 4.32 Case Beta – 2.0 Leadership

4.3.2.3 Customer / Market Focus (3.0):

Beta's approach to defining customer requirements is intentional and formal approach. This appears, at least in part, necessitated by their type of business. This is not to say that there is not an opportunity for improvement. Also there also appears to be a very clear understanding regarding Beta's source of differentiation relative to its competition.

Beta uses a formal method for translating customer requirements into detail design packages. Historically design has been the source of major problems both in production and in the field as evidenced by high warranty costs. However, it appears as if the reduction of design errors has contributed greatly to the substantial reduction of warranty costs over the last several years. Interestingly, it appears as if there is remaining room for further improvement, since over half of the warranty corrective actions continue to deal primarily with design issues. Also, it was noted that there is not a regular review of closed jobs including customer feedback. This appears to represent a good source of feedback to drive more effective counter measures.

Interestingly, neither Beta nor its competitors, have technological advantage in terms of product performance. This may be because the products are relatively simple, just varying in terms of size, shape, diameter, and length depending upon customer's electrical requirements and job site obstructions. Since product performance is essentially the same, Beta has determined the best way to distinguish itself from its competitors is to focus on excellence in service. Beta perceives itself to be the leader in its market in service and after sales support.

Lead-time has not typically been used as a competitive weapon. Typical lead-times quoted for different types of jobs are industry standard. For example, the lead-time for IPB is 4-6 months and rectangular products are 2-3 months. Lead-times are generally based on the lead-times required to acquire key components (e.g., copper, aluminum, and steel). According to information from the sales manager, quick response and lead-time may make a difference for about 30% of the orders. It is, as yet, untested but in these may represent an opportunity to charge a premium.

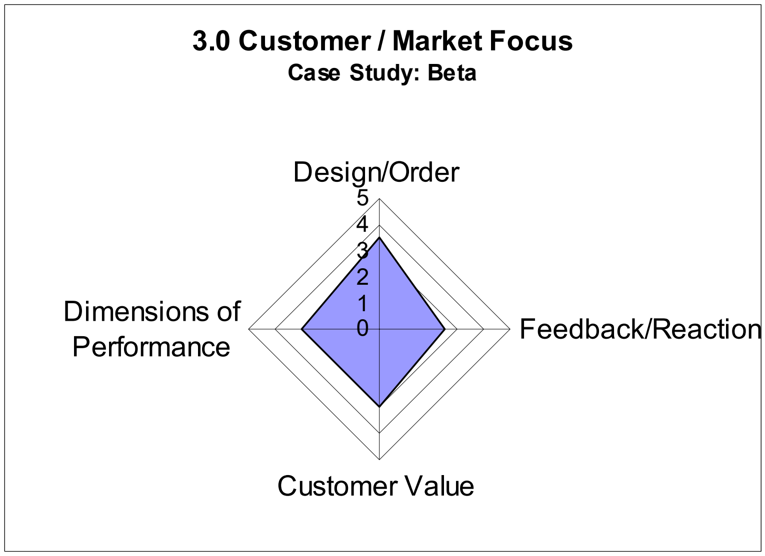


Figure 4.33 Case Beta – 3.0 Customer/Market Focus

4.3.2.4 Information and Knowledge Management (4.0):

Generally, Beta exists within an information rich environment. However, there appears to be real opportunity for improving access to critical pieces of data so that improvements efforts are effectively guided. Also, access to basic product and process knowledge appears to be adequate.

However, data is fragmented along functional lines and numerous handoffs between departments provide opportunities for delays and miscommunications. It also appears as if key pieces of information are either not available (e.g., adequate measure of overall capacity), not easily obtained (e.g., profitability by product line), or not reliable (percentage of on-time shipments). On the other hand, some information is readily available like tracking of actual hours compared to budgeted, and actual to budgeted costs. Data that supports traditional quality measures like scrap, rework, and warranty occurrences appear adequate and frequently relied upon.

Product knowledge is retained in a variety of ways which include welding quality manual, job prints. Also job related data are archived under a director structure on the server.

However, there is an opportunity for capturing design theory for teaching others internally and for discussion with customers.

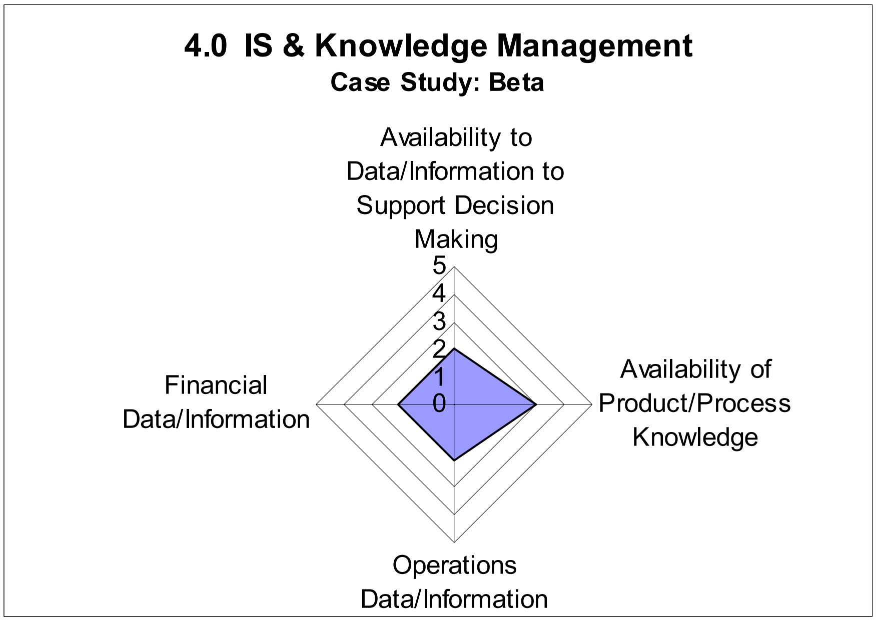


Figure 4.34 Case Beta – 4.0 IS and Knowledge Management

4.3.2.5 Human Resources (5.0):

Overall teamwork is valued at Beta, however, formal and highly structured team activity has been somewhat infrequent. Personal qualities that lead to effective teaming are screened during the interview process and encouraged through their annual review process.

Due to a relatively large contingent of employees that have been with the company for many years, this has resulted in a broad knowledge of other job functions. This is because of the cyclic nature of the industry during times of contraction, job span increases due to layoffs and during times of growth job spans contract. In addition, close communication typically associated with a small company adds to this knowledge. Despite cross functional knowledge, people's behaviors are primarily driven by functional concerns. This is particularly true in the office and in the administrative support areas. The mastery of key skills has been identified and developed within the plant, but not as much in engineering and in the administrative areas.

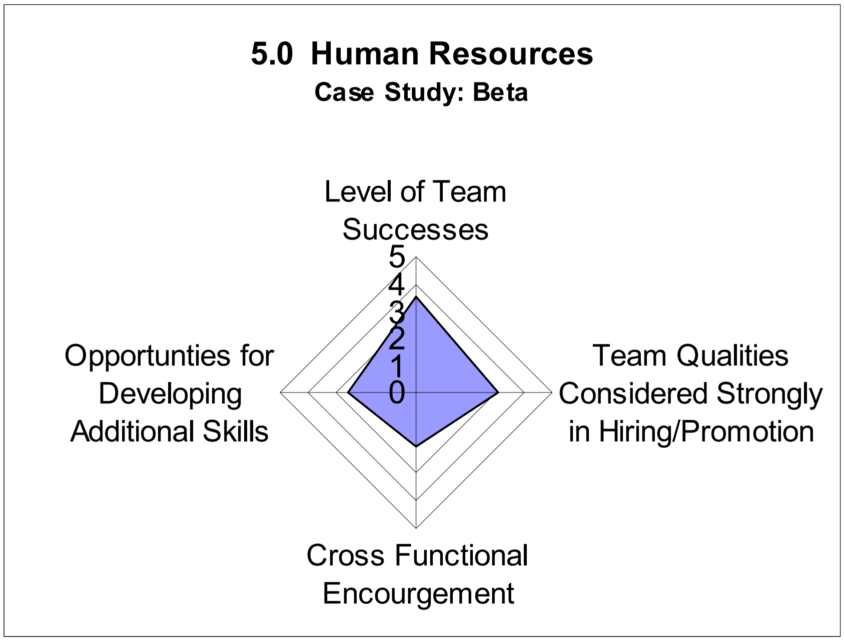


Figure 4.35 Case Beta – 5.0 Human Resources

4.3.2.6 Development of Products and Processes (6.0):

Most of Beta's engineering and design efforts are spent engineering each order separately. Relatively little effort has been invested in development of new fundamental products or components. This may be indicative of the power construction industry and the Beta's specific markets. However, Beta's has recently embarked on an initiative to start developing a more standardized approach to its products. There is some evidence that the introduction of at least some measure of product standardization has improved quality and responsiveness of design and production.

At a cursory level, apparently there is much value in continuing their efforts to standardize, while maintaining their ability to craft custom final product configurations. This will enable the company to address unique requirements of each job in a more efficient manner. Possible solutions lie in concepts of parametric design, modular design concepts, delayed differentiation.

Beta has very slowly introduced new process technologies to the shop floor. This appears to come from both a desire to remain flexible and a general corporate philosophy of not investing heavily in capital assets. Beta's reaction to the cyclical nature of their business appears as the root of both of these issues.

Most of the production processes are manual (e.g., welding, painting) or involve mature manufacturing process technologies (e.g., presses, cutter, CNC…). . In contrast, their competition has invested more heavily in fixed automation. The biggest challenge for Beta in terms of process development is not so much investing in new technologies for automating an individual process steps, but in realigning the overall plant to facilitate product flow. This initiative has just started with a series of 5S kaizen events, which are planned to spread across the entire plant within the next few months. Early results for the rectangular product line have been positive. It is anticipated that through this initiative Beta has a greater opportunity for achieving flexibility and responsiveness

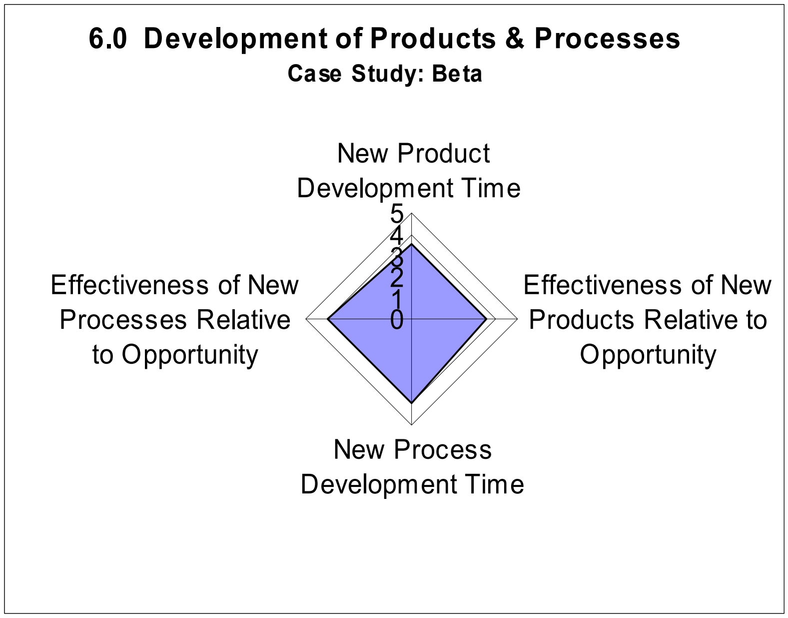


Figure 4.36 Case Beta – 6.0 Development of Products and Processes

<u>4.3.2.7 Product and Process Characterization (7.0):</u>

Beta's products are characterized by relatively long service life. It is not uncommon for their products to operate successfully in the field for 30-40 years. The fundamental research & development for establishing core product design was conducted many years ago. Their products operate in a somewhat complex environment, but basic product design is not overly complex. Current design efforts consist of determining the best product configuration for the customer's specific job site. The product variety is high primarily due to the combinations of conductor size, enclosure size, enclosure type, and insulator types. Each job is engineered to order not only from the standpoint of electrical requirements, but also based on how the bus system is routed at each job site in order to avoid obstructions. The structural steel supports also have to be designed based on the bus routing.

Processes are characterized by somewhat high level of vertical integration, functional plant layout, and minimal excess capacity. Current orders are strong and the backlog of orders for the next several months is very close to capacity, at least as currently measured. Capacity is measured by total available man hours and man hours allocated to jobs based upon preliminary estimates. This calculation is very straightforward, but management is not satisfied with its relative accuracy. The fact that actual capacity is derived by the limits set by the system's constraint is not reflected in Beta's production planning. While the plant lay-out is nominally functional, it is anticipated that the kaizen events will result in a move toward a cellular concept.

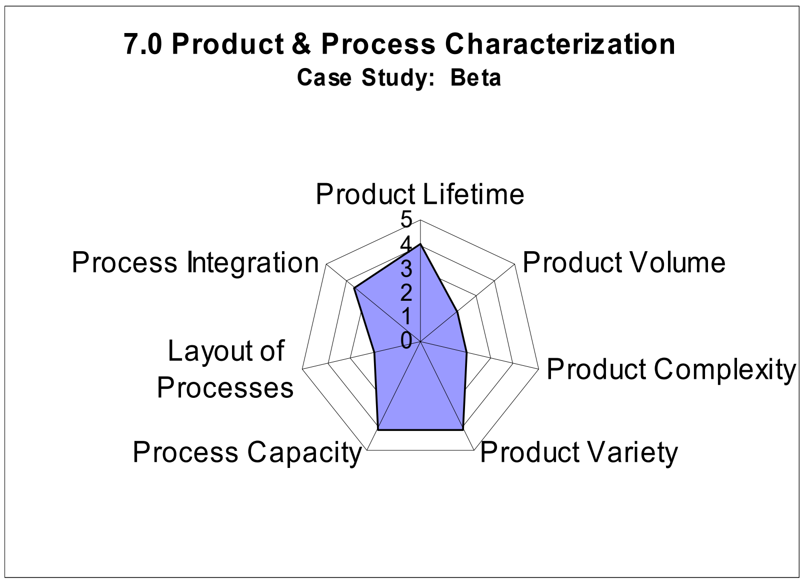


Figure 4.37 Case Beta – 7.0 Product & Process Characterization

4.3.2.8 Management of Extended Enterprise (8.0):

Beta appears to communicate clearly the ordering requirements specific to its vendors in terms of product features (sizes, shape, dimensions, etc.). However, due dates and quantities change frequently. At times these changes occur very late in the project, resulting in scheduling problems both with the suppliers and within the plant. Some of the reasons for the changes are changing customer requirements, delays in getting information from the customer, and delays from Beta's design group.

Purchases are driven primarily from specific jobs, 75% of the items representing about 95% of the purchased costs. Job specific ordering is done for the major component requirements like aluminum plates, enclosures, copper, steel structures, and insulators. Many of these are chronically long lead-time items (e.g., aluminum lead time is 14 weeks, copper is 7 weeks). These component lead-times are relatively long. The overall job lead-time ranges from 4-6 months depending upon complexity. There may be some reductions enabled by storing materials in a more raw condition (e.g., coils) rather than having to custom order for each job. However, at present the plant does not have the equipment needed to cut to order. Other items are stocked locally and it may be possible to move toward daily deliveries.

The biggest challenge to Beta's developing a more robust delivery system is the process of designing and acquiring steel structures. A recent sample of 10 jobs revealed that 8 of these jobs were in danger of not meeting the customer due date requirements because of structural steel. These structures not only are produced late in the job schedule, but require multiple vendors. Due to its criticality, the process is briefly outlined as follows.

The structural components are usually the last items designed and the first items on the order to ship. This is because job site information from the customer must be finalized in terms of routing around job site obstructions. Once the requirements are determined, the design work is sent to an outside engineering firm. Once the structural design is complete, the steel supplier fabricates and then galvanizes the components. Finally these structures are received at Beta where additional fabrication is required prior to shipping.

In general, vendor delivery performance is not measured reliably, nor is Beta's delivery performance to its customer. Ultimately these measurement problems stem from changes in the customer's schedule, which is translated to Beta and amplified to Beta's supply chain. Of the people interviewed during the assessment, there was very little credibility placed on the vendor's on-time delivery performance. Beta's on-time delivery performance is approximately 60% and was not viewed as a problem because it was measured against a date set when the PO was issued and is often no longer relevant to the true customer requirement. This problem, masks and inhibits Beta's ability to set clear requirements and to drive its performance against that requirement. This is an essential discipline that must be developed so that waste is removed from internal processes and processes are reengineered for increased performance.

Beta turns its inventory an average of 6 times per year. Approximately $3 million dollars is held by Beta, which is split evenly between raw and WIP. Virtually no inventory is held at the finished goods stage.

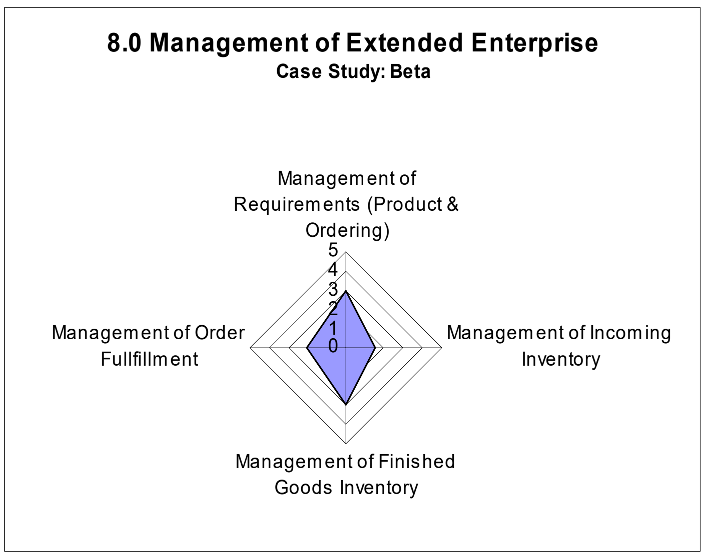


Figure 4.38 Case Beta – 8.0 Management of Extended Enterprise

4.3.2.9 Approach to Continuous Improvement (9.0):

Overall Beta's approach to continuous improvement has been shaped primarily by ISO 9000 type of requirements. The company has a registered quality system compliant with ISO

9001. Therefore measures like warranty, scrap, and number of corrective actions have dominated. However, there is a gap in terms of the absence of strategic measures like reliable due date performance, robust measure of available capacity, job lead-time, and profitability by job type.

While clearly there is many highly experienced and knowledgeable people at the company, there was not a strong understanding of the critical role of key processes. For example, the problems experienced with structural steel were known, but the strategic value in streamlining this process was neither articulated nor clearly understood. This is evidenced by the lack of any major improvement initiative to attack this problem. Another example, was their inability to clearly state which process under what condition serves as the constraint; and therefore defines system capacity. Opinions surfaced during the discussions on this subject, although no data was available to substantiate claims.

The use of lean manufacturing principles to eliminate waste on the plant floor is at a very early stage via the 5S kaizen events. However, prior to the recent 5S work, no evidence was found concerning the systematic implementation of lean principles. Considering Beta's cyclical business environment, an opportunity exists for designing workstations for linearity (i.e., the ability to expand and contract labor content based on the takt time). As successful continuous improvement efforts continue, particularly on the shop floor, consideration should be given to how employees are motivated to buy-in given the cyclical condition of their business.

A strong record of accomplishment exists in terms of improving traditional costs of poor quality as evidence by a dramatic reduction scrap and warranty costs over the last several years.

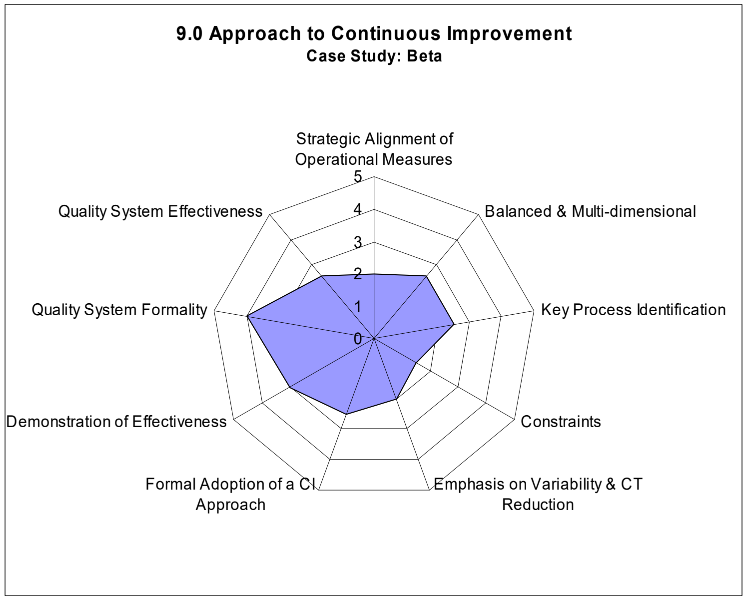


Figure 4.39 Case Beta – 9.0 Approach to Continuous Improvement

4.3.2.10 Enterprise Financial Health (10.0):

Overall there is capital available for investment and cash flow does not restrict operations. However, capital justifications are looked at within very short time frames due to uncertainty caused by their cyclical business environment. Typically, justifications are justified based on backlog sales or very near term forecast of almost certain sales. Therefore, payback with a satisfactory return needs to occur within 18 to 24 months. This corporate philosophy has resulted in the manufacturing operations at Beta to be labor dominated with a limited amount of fixed automation.

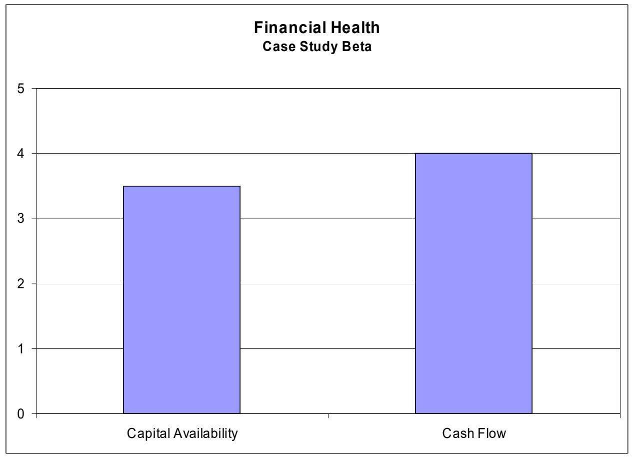


Figure 4.40   Case Beta – 10.0 Financial Health

4.3.2.11 Overview of Beta's MET Fit:

The following chart illustrates Beta's score across the 10 major attributes or taxons contained within the MET. In general the biggest opportunities exist in addressing the management of extended enterprise, approach to continuous improvement, and information system and knowledge management.

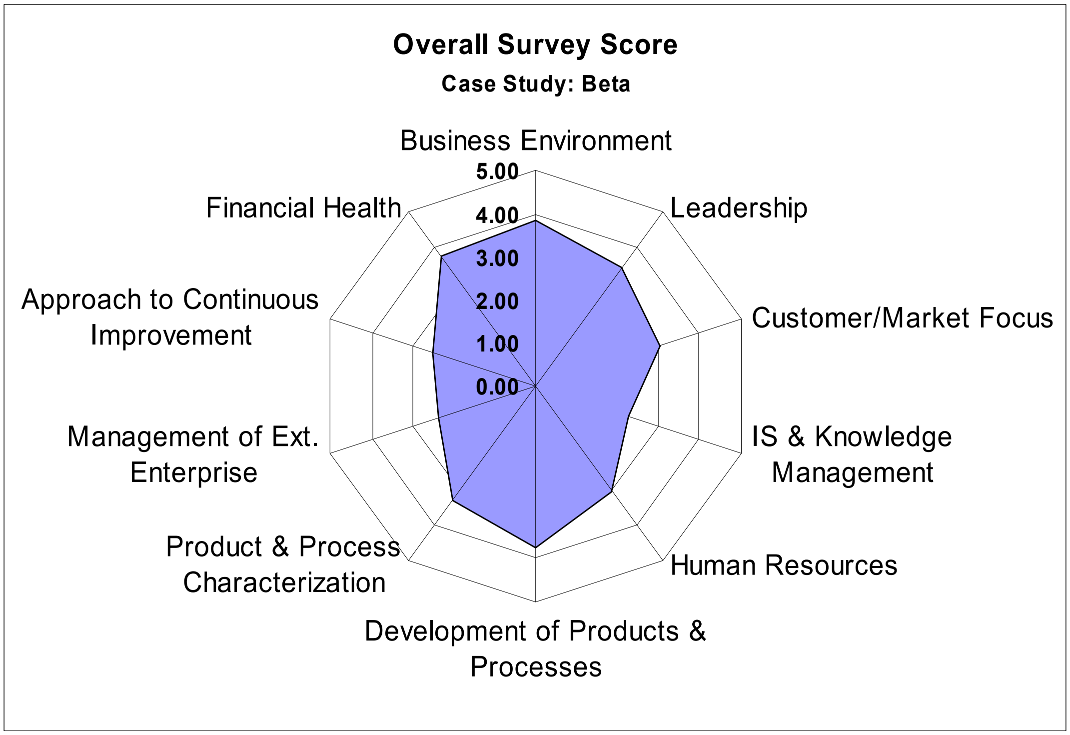


Figure 4.41 Case Beta – Overall Fit within MET

Therefore, the client "Beta" is classified within the Manufacturing Enterprise Taxonomy (MET) at the time of this assessment in the following table.

1.0 Business Environment			Score	Average for Category	Average for Taxon
	1.1 Competitive Environment	1.1.1 Intensity of Competition	3	3.00	3.83
		1.2.1 Stability/Emerging Threats	3		
	1.2 Regulatory Environment	1.2.1 Product Regulations:	4.5	4.50	
		1.2.2 Process Regulations:	4.5		
	1.3 Market Conditions	1.3.1 Seasonality Effect	4.5	4.00	
		1.3.2 Level of Growth	3.5		
2.0 Leadership					
	2.1 Strategic Planning & Deployment	2.1.1 Formal Strategy	4.5	4.00	3.38
		2.1.2 Strategy Deployment	3.5		
	2.2 Culture of Empowerment	2.2.1 Level of Participation	2.5	2.75	
		2.2.2 Effectiveness of Participation	3		
3.0 Customer / Market Focus					
	3.1 Translation of Requirements	3.1.1 Design/Order	3.5	3.00	3.00
		3.1.2 Feedback/Reaction	2.5		
	3.2 Positioning / Value	3.2.1 Customer Value	3	3.00	
		3.2.2 Dimensions of Performance	3		
4.0 Information System & Knowledge Management					
	4.1 Access to Information & Knowledge	4.1.1 Availability to Data/Information to Support Decision Making	2	2.50	2.25
		4.1.2 Availability of Product/Process Knowledge	3		
	4.2 Supportive of Improvement Efforts	4.2.1 Operations Data/Information	2	2.00	
		4.2.2 Financial Data/Information	2		
5.0 Human Resources					
	5.1 Maturity in Teaming	5.1.1 Level of Team Successes	3.5	3.50	3.00
		5.1.2 Team Qualities Considered Strongly in Hiring/Promotion	3.5		
	5.2 Employee Skill Level	5.2.1 Cross Functional Encourgement	2.5	2.50	
		5.2.2 Opportunties for Developing Additional Skills	2.5		
6.0 Development of Products & Processes					
	6.1 Product Development	6.1.1 New Product Development Time	3.5	3.50	3.75
		6.1.2 Effectiveness of New Products Relative to Opportunity	3.5		
	6.2 Process Development	6.2.1 New Process Development Time	4	4.00	
		6.2.2 Effectiveness of New Processes Relative to Opportunity	4		
7.0 Product & Process Characterization					
	7.1 Product Characterization	7.1.1 Product Lifetime	4	3.00	3.28
		7.1.2 Product Volume	2		
		7.1.3 Product Complexity	2		
		7.1.4 Product Variety	4		
	7.2 Process Characterization	7.2.1 Process Capacity	4	3.17	
		7.2.2 Layout of Processes	2		
		7.2.3 Process Integration	3.5		
	7.3 Product-Process Characterization	7.3.1 Goldratt's VAT Logical Product-Process	4	4.00	
		7.3.2 Hayes-Wheelwright Matrix	4		
8.0 Management of Extended Enterprise					
	8.1 Supply Chain Management	8.1.1 Management of Requirements (Product & Ordering)	3	2.25	2.38
		8.1.2 Management of Incoming Inventory	1.5		
	8.2 Distribution Chain Management	8.2.1 Management of Finished Goods Inventory	3	2.50	
		8.2.2 Management of Order Fullfillment	2		
9.0 Approach to Continuous Improvement					
	9.1 Performance Measures	9.1.1 Strategic Alignment of Operational Measures	2	2.25	2.50
		9.1.2 Balanced & Multi-dimensional	2.5		
	9.2 Process Focus	9.2.1 Key Process Identification	2.5	2.00	
		9.2.2 Constraints	1.5		
		9.2.3 Emphasis on Variability & CT Reduction	2		
	9.3 Use of Specific World Class Practices	9.3.1 Formal Adoption of a CI Approach	2.5	2.75	
		9.3.2 Demonstration of Effectiveness	3		
	9.4 Quality System	9.4.1 Formal System	4	3.25	
		9.4.2 Demonstration of Effectiveness	2.5		
10.0 Enterprise Financial Health					
	10.1 Capital Availability	10.1.1 Capital Availability	3.5	3.50	3.75
	10.2 Liquidity	10.2.1 Cash Flow	4	4.00	

Figure 4.42 Case Beta – Detail Fit within MET

The final outcome of the TBAM evaluation stage is the identification of the the client's undesirable effects (UDEs). As the following figure illustrates a total of 9 UDEs were identified during the on-site survey. The UDEs were prioritized by the client's senior management representative at the conclusion of the on-site visit. The scores associated with each UDE are shown in the figure below.

	Prioritization of UDEs Identified During the MET Survey		Case: Beta
	UDE	Overall	Cumulative Percentage
1	***Steel delivery is later than desired***	***30***	***30%***
2	***Standard LT's limiting additional volume with higher margins***	***20***	***50%***
3	***Capacity is unclear and not managed as a performance measure***	***20***	***70%***
4	Information resides within silo's and does not flow easily across functions.	10	***80%***
5	Measurement of "On Time" shipments to customers is not reliable.	5	***85%***
6	Measurement of Vendor "on-time" performance is not clear.	5	***90%***
7	Inventory dollar value is "high" (i.e., turns are "low")	5	***95%***
8	Every job is treated as "new"	5	***100%***
9	Functional interests drives behaviors more than cross functional needs.	0	***100%***
	Total	100	

Figure 4.43 Case Beta – UDE Prioritization

The TBAM methodology requires the top three UDEs to serve as inputs into the diagnosis phase. These UDEs are probed on during the development of the client's Current Reality Tree (CRT).

4.3.3. Beta Diagnosis

The purpose of the diagnosis stage is to develop a logical linkage between the UDEs (i.e., symptoms) and a relatively small set of root causes. This is accomplished by the construction of the Current Reality Tree (CRT).

The CRT is constructed by picking one of the three previously identified UDEs and probing the next level of causes. Those causes are then treated as effects driven by lower level causes. This procedure is repeated until a large number of the UDEs appear to be related to a relatively few number of root causes.

The following narrative provides the reader with an overview of Beta's current reality tree. The three UDEs selected for use as input into the construction of the CRT are listed and labeled below.

- UDE-1: Steel delivery is later than desired.
- UDE-2: Standard lead-times are limiting additional volume with higher margins.
- UDE-3: Capacity is not managed as a performance measure.

These UDEs were reviewed and UDE-2 was selected for initial probing by the assessment team because it was believed, at least initially, that the assessment possessed a higher level of intuition about this UDE than the other two.

Explanation of UDEs

UDE-2 is driven by the sets of following causes as illustrated in CRT Figure #1.

- If "Customers with LT sensitive jobs will pay higher margins" and if "lead time sensitive jobs are not sought out" then "standard lead times are limiting higher margin volume."
- Ultimately the entity "lead time sensitive jobs are not sought out is driven by three branches of cause and effect relationships.
  - The first branch is derived from UDE-3 "capacity is not managed as a performance measure."
  - The second branch is derived from the entity number 100 "lead times are driven by the quoted lead-time of key raw materials."
  - The third branch results from the entity number 300 "lack of routine ability to hit targeted ship dates."

Each of these subordinate branches are traced out as follows.

- The UDE-3 is derived from entity # 200 “capacity is not effectively measured.” This entity is mapped on Beta’s CRT Figure 2. As can be determined form this figure the root of entity 200 and by implication the root of UDE-3 is RT-1 “No loading by resource (workstation) for a given product line.
- Entity # 100 is mapped out on Beta’s CRT Figure 3 and 4. From Figure 3 entity 100 is driven ultimately by entity number 110 “No local ability to cut to raw material to order.” Entity #110 is explained on Beta CRT figure 4 where it is derived from RT-2 “No market/operations plan on the business value of rapid lead time capability.”
- Entity number 300 is observed in Beta CRT Figure 5 to be derived ultimately from the entity number 200 (which emerges from RT-1 on Beta CRT Figure 2) and RT-3 “waste reduction is not actively pursued in order to reduce lead time.”

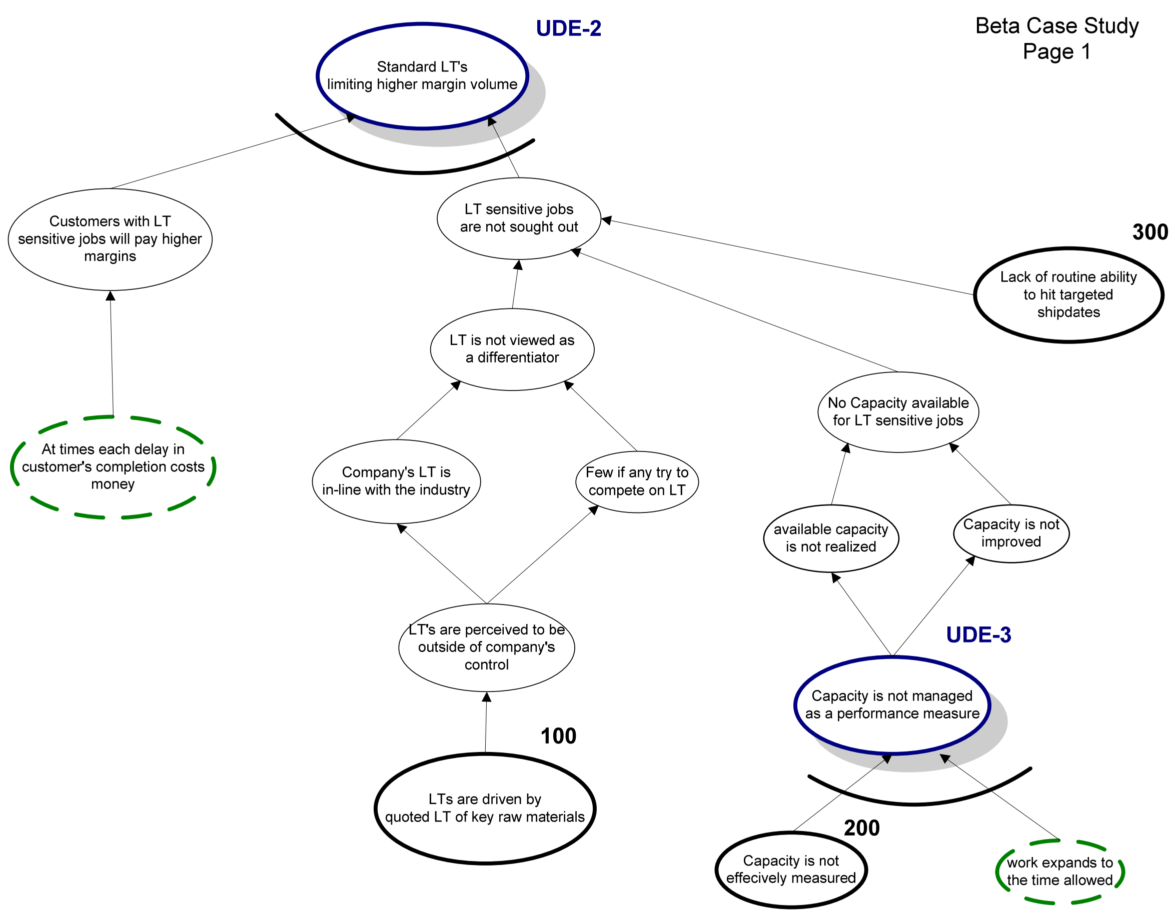


Figure 4.44 Case Beta – CRT Page 1

Beta Case Study
Page 2

Figure 4.45 Case Beta – CRT Page 2

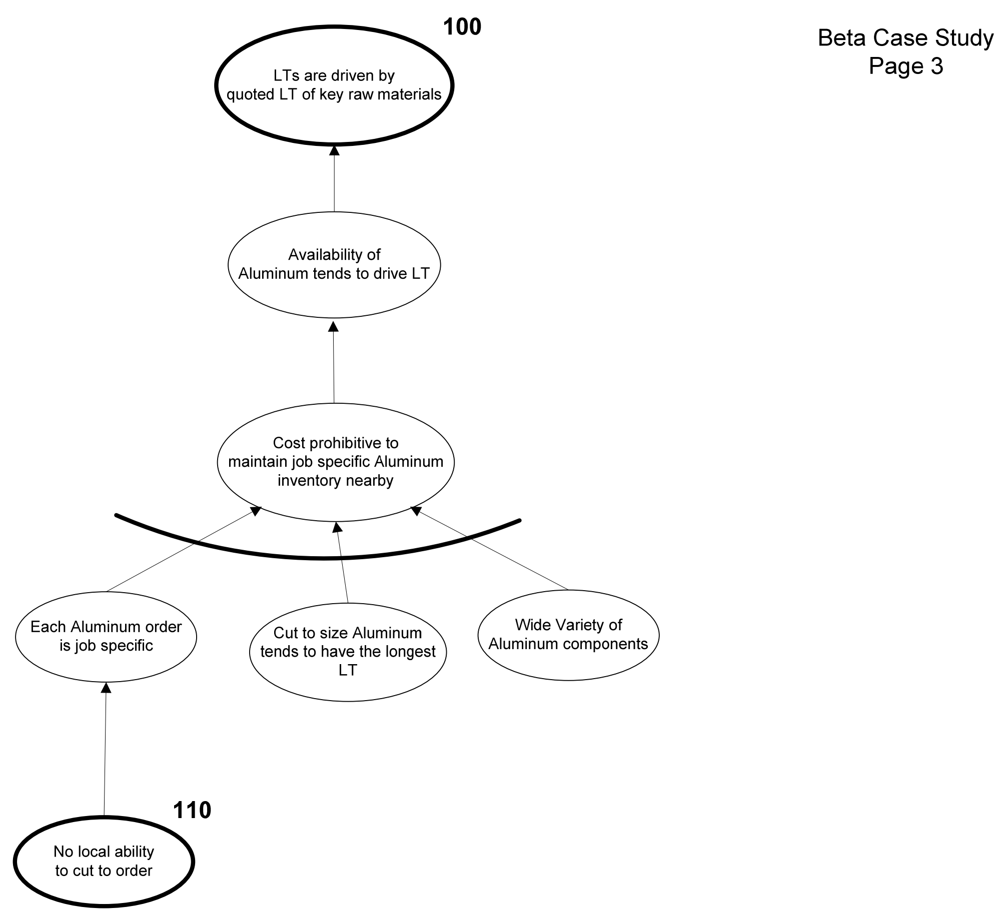


Figure 4.46 Case Beta – CRT Page 3

Beta Case Study
Page 4

Figure 4.47 Case Beta – CRT Page 4

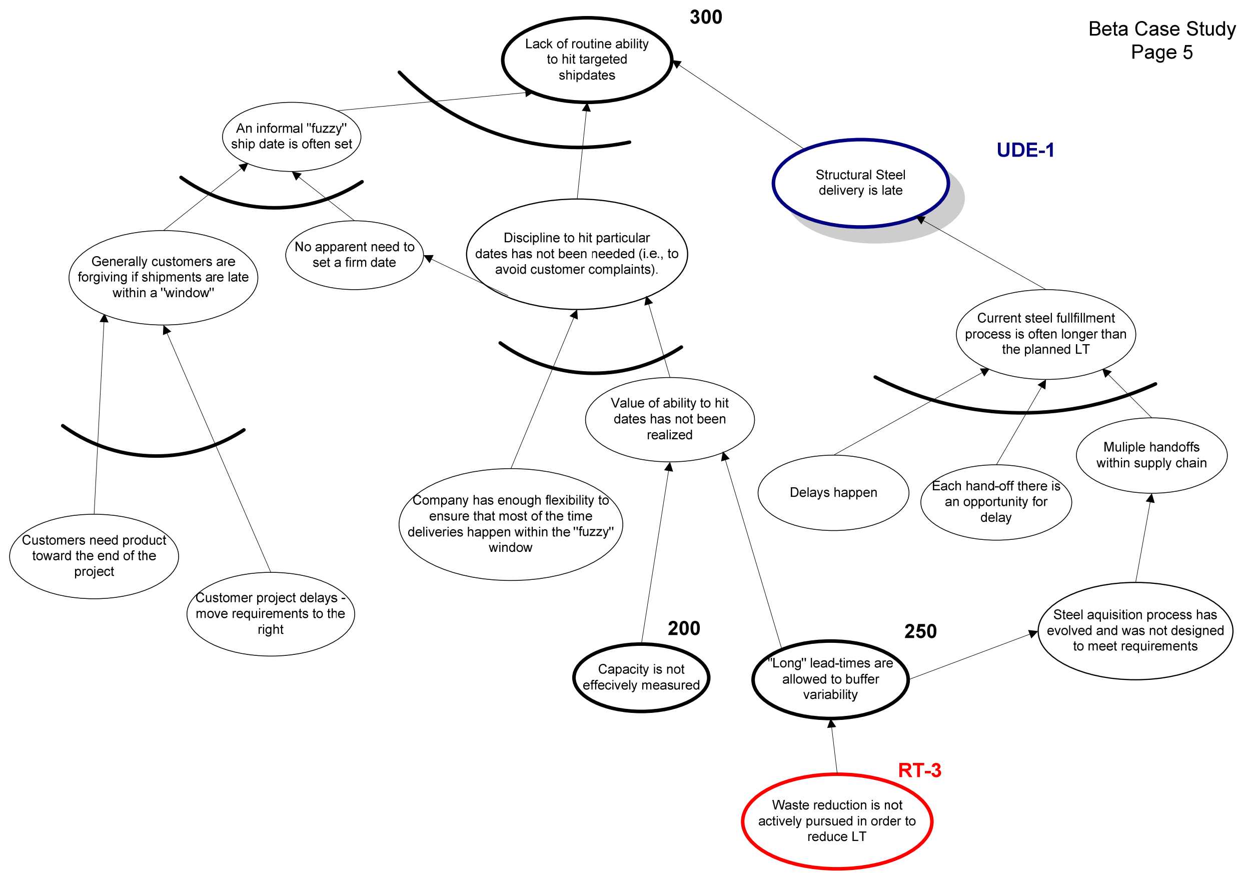


Figure 4.48 Case Beta – CRT Page 5

The following table summarizes the results from the application of the CRT. Notice that there is not a one-to-one correspondence between the three UDEs and the three roots. Their relationships stem from the construction of the CRT, as established by the assessment team in collaboration with the SMR from the client, connecting the UDEs with root causes.

UDEs	Root Causes
• **UDE-1:**. Structural steel delivery is late. • **UDE-2 :** Standard Lead-Time's are limiting higher margin volume • **UDE-3:** Capacity is not managed as a performance measure	• **RT-1:** No loading by resource (i.e., workstation) for a given product line. • **RT-2:** No market operations plan on business value of the development of a rapid lead-time capability. • **RT-3:** Waste reduction is not actively pursued in order to reduce lead-time.

Note: There is not a one-to-one relationship between the three UDEs and the three root causes. The relationships are defined by the CRT.

Figure 4.49 Case Beta – Summary of UDEs and Root Causes

4.3.4 Beta Prescription

The purpose of the prescription stage is to develop a set of recommendations targeted at elimination of the root causes (RT-1, RT-2, RT-3). The first step is to prioritize the PST elements from the standpoint of relevance to the case's set of root causes. This was accomplished by the assessment team multi-voting each of the root causes across the 95 elements of the PST. The results of the multi-vote are found in Figure 4.50. The multi-vote resulted in 14 PST selections, they accounted for 80% of the total votes. These selections were then used during the panel review process to provide an external reference on issues of validity and reliability. It should be noted for the Beta case only, the SMR's judgment was included in the assessment teams multi-voting activity. This was tried on this case study due to the SMR's extensive knowledge of the PST elements and a high willingness of SMR to participate.

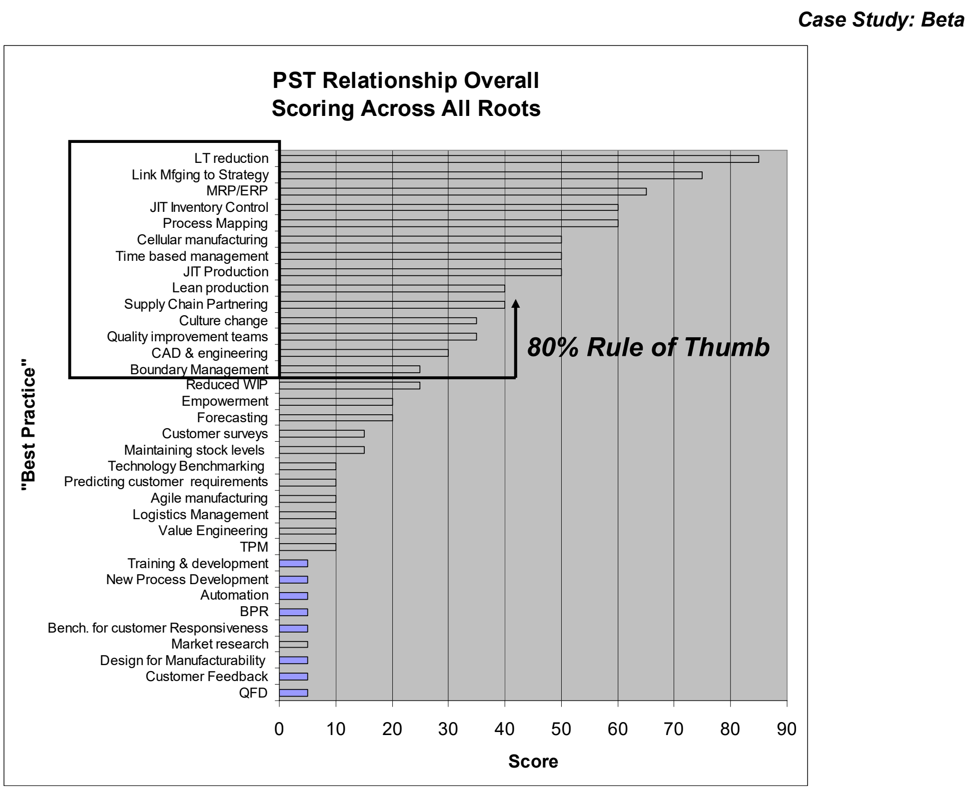


Figure 4.50 Case Beta – PST Elements Scored Across all Root Causes

Recommendation #1 addresses the root labeled "no loading by resource (i.e., workstation) for a given product line." As shown in the By observation of the Figure 4.45 the following entities are driven by RT-1.

- "Capacity data is not available at a sufficient enough level of detail."
- "Can't predict the location of the constraint and under what condition"
- "Capacity is not effectively measured"
- "Capacity is not managed as a performance measure" (UDE-3)

The selection from the PST resulted in the following best practice elements as most relevant to RT-1.

- 3.D-4 MRP/ERP
- 4.B-7 Link manufacturing to strategy
- 1.B-3 Process Mapping
- 2.B-3 JIT Inventory Control
- 1.C-4 LT Reduction
- 1.B-2 JIT Production
- 3.A-1 Quality Improvement Teams

It is within this context that Recommendation #1 was formulated.

> *Recommendation #1:* Develop ability to compare requirements with the capacity of key workstations. This will enable the constraint to be identified and appropriate operational measures to be tracked. This should guide improvement actions for increasing system capacity.

This approach is summarized in the following Figure 4.51.

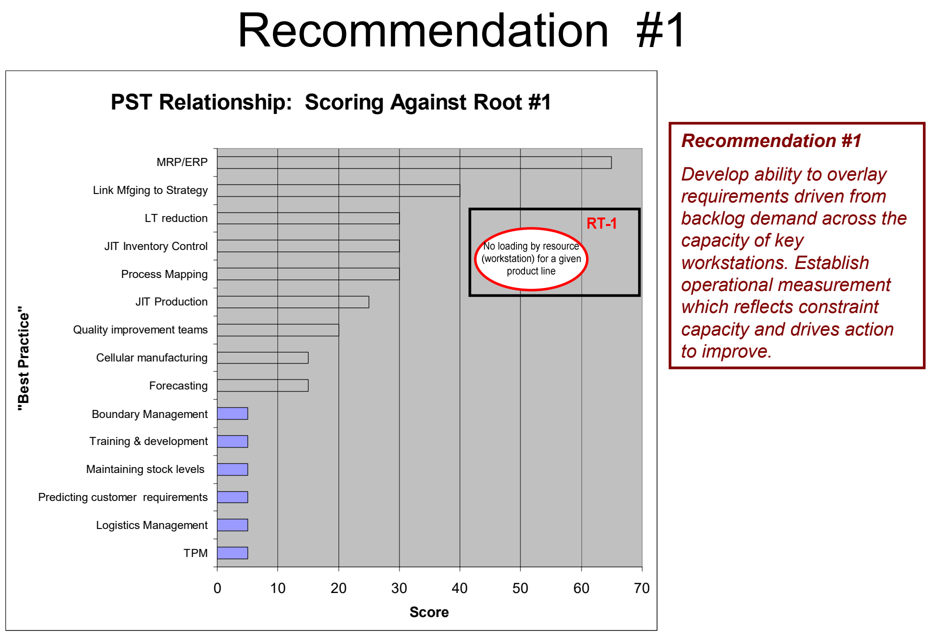


Figure 4.51 Case Beta - Development of Recommendation #1

The following Figure illustrates how the PST "best practice" elements map into the defined recommendation.

Linking PST Elements to Recommendation #1

Recommendation #1

*Develop ability to compare requirements with the capacity of key workstations **(3.D-4)**. This will enable the constraint to be identified **(1.B-3)** and appropriate operational measures to be tracked **(1.B-2)**. This should guide improvement actions **(3.A-1, 1.B-2)** for increasing system capacity **(4.B-7)**.*

Prioritized PST Elements for Root #1

Ref #	PST Element
3.D-4	MRP/ERP
4.B-7	Link Mfging to Strategy
1.B-3	Process Mapping
2.B-3	JIT Inventory Control
1.C-4	LT reduction
1.B-2	JIT Production
3.A-1	Quality improvement teams

Figure 4.52 Case Beta: Linking PST Elements to Recommendation #1

Recommendation # 2 focused on the root cause "no market/operations plan on developing the business value of rapid LT capability" (RT-2). The CRT resulted in the following entities that are driven from RT-2.

- "Profitability due to quick response program is not known."
- "Company has no local ability to facility rapid processing of key raw material."
- "LT's are driven by availability of key raw material."

The selection from the PST resulted in the identification of the following best practices as being most relevant to RT-2.

- 2.A-1 Supply Chain Partnering
- 4.B-7 Link manufacturing to strategy
- 1.C-4 LT Reduction
- 1.D-4 CAD and engineering

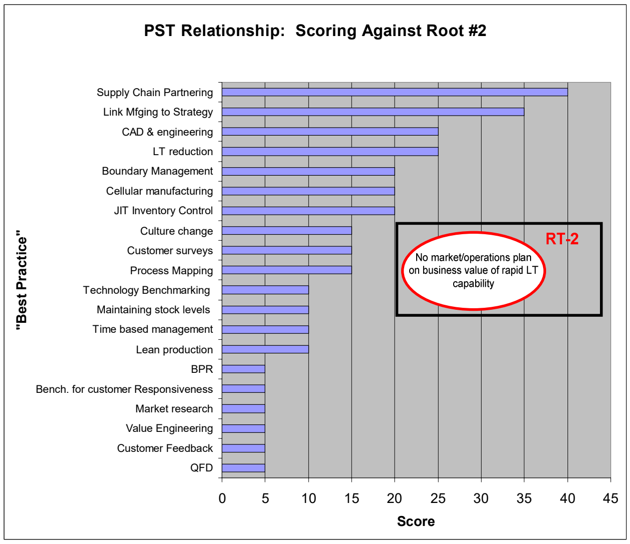
- 2.B-3 JIT inventory control
- 3.C-3 Cellular manufacturing
- 3.E-4 Boundary Management
- 1.B-3 Process Mapping
- 4.C-3 Customer surveys
- 4.E-4 Culture change

It was within this context that the following was developed in terms of a recommendation.

> Recommendation #2: Develop an overall business plan for establishing the value of rapid lead-time capability. This includes exploring partnerships with suppliers of key raw materials, reorganizing production operations to facilitate flow, finding ways of streamlining pre-production operations, and rationalizing appropriate capital investments. Of particular promise are ways to reduce design complexity (e.g., parametric CAD).

This approach was summarized in Figure 4.53.

Recommendation #2



Recommendation #2

Develop an overall business plan for establishing the value of adopting a rapid lead-time capability. This should include exploring innovative partnerships with suppliers of key raw materials, rationalizing appropriate capital investments, reorganize plant and support operations to improve the flow of products across functions, and look for ways of reducing design complexity (e.g., parametric CAD).

Figure 4.53 Case Beta - Development of Recommendation #2

The following illustrates how the selected best practice elements from the PST were mapped into recommendation #2.

Case Study: Beta

Linking PST Elements to Recommendation #2

Recommendation #2

*Develop an overall business plan for establishing the value of rapid lead-time capability **(1.C-4, 4.C-3)**. This includes exploring partnerships with suppliers of key raw materials **(2.A-1)**, reorganizing production operations to facilitate flow **(3.C-3, 1.B-3, 2.B-3)**, finding ways of streamlining pre-production operations **(3.E-4)**, and rationalizing appropriate capital investments **(4.B-7)**. Of particular promise are ways to reduce design complexity - e.g., parametric CAD **(1.D-4)** .*

Prioritized PST Elements for Root #2

Ref #	PST Element
2.A-1	Supply Chain Partnering
4.B-7	Link Mfging to Strategy
1.C-4	LT reduction
1.D-4	CAD & engineering
2.B-3	JIT Inventory Control
3.C-3	Cellular manufacturing
3.E-4	Boundary Management
1.B-3	Process Mapping
4.C-3	Customer surveys
4.E-4	Culture change

Figure 4.54 Case Beta - Linking PST Elements to Recommendation #2

Recommendation # 3 attacks the root “ waste reduction is not actively pursued in order to reduce LT” (i.e., RT-3). The CRT shows that the following entities are driven from RT-2.

- “long lead-times are allowed to buffer variability”
- “discipline to hit particular due dates has not been needed in order to avoid customer complaints.”
- “structural steel delivery is late.”

The selection from the PST resulted in the identification of the following best practices as being most relevant to RT-3.

- 4.B-4 Time based management
- 4.B-1 Lean production
- 1.C-4 LT reduction
- 1.B-1 Reduced WIP
- 1.B-2 JIT Production

- 4.E-2 Empowerment
- 3.A-1 Quality Improvement Teams
- 1.B-3 Process mapping
- 3.C-3 Cellular manufacturing

It was within this context that the following was developed in terms of a recommendation.

> Recommendation #3: Develop a value stream map both "as is" and "to be"" for lead-time sensitive products. The "as is" case illustrates the waste involved in the total process. This should include the key activities (i.e., receipt, design, purchase, and fabricate), and the calculation of percent "value add" time for comparison against world class performance. The "to be" case establishes the vision for substantial process improvement. The mapping and transition effort should include a broad cross section of team members.

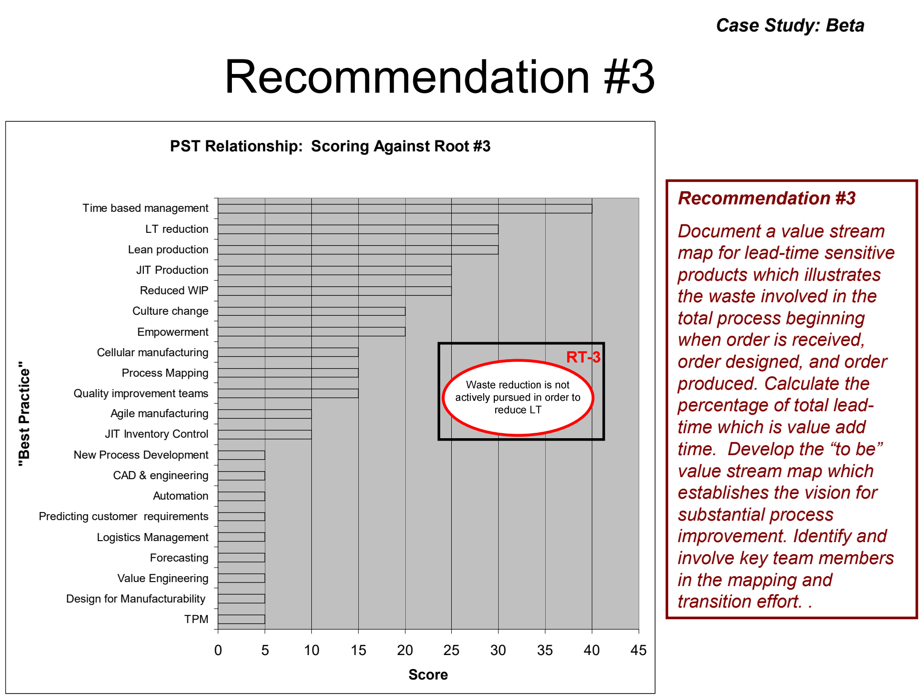


Figure 4.55 Case Beta - Development of Recommendation #3

The following illustrates how the selected best practice elements from the PST were mapped into recommendation #2.

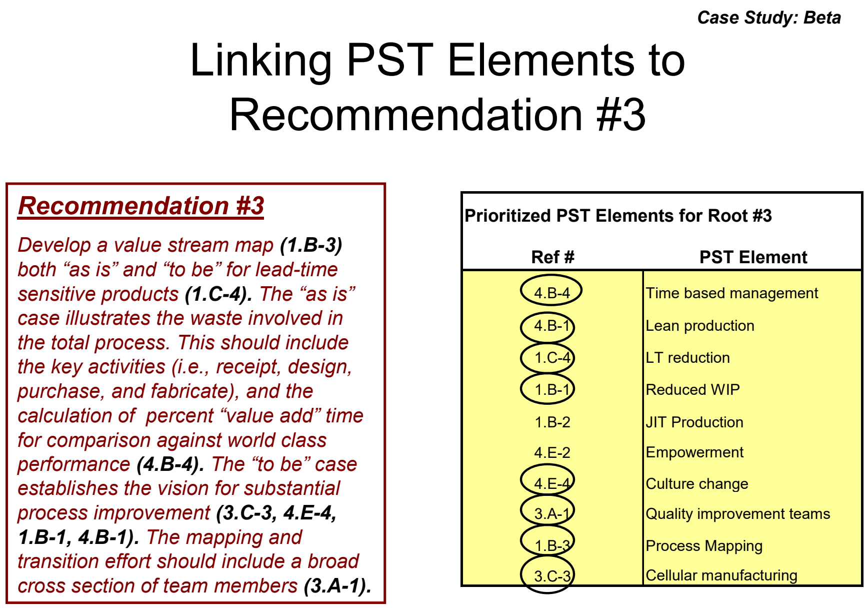


Figure 4.56 Case Beta - Linking PST Elements to Recommendation #3

The prescription stage for case Beta is outlined in the Figure below. The objective of the TBAM approach is illustrated within this case, which is to translate UDEs into recommendations that target core problems facing the firm at the time of the assessment. This approach for case Beta is outlined below.

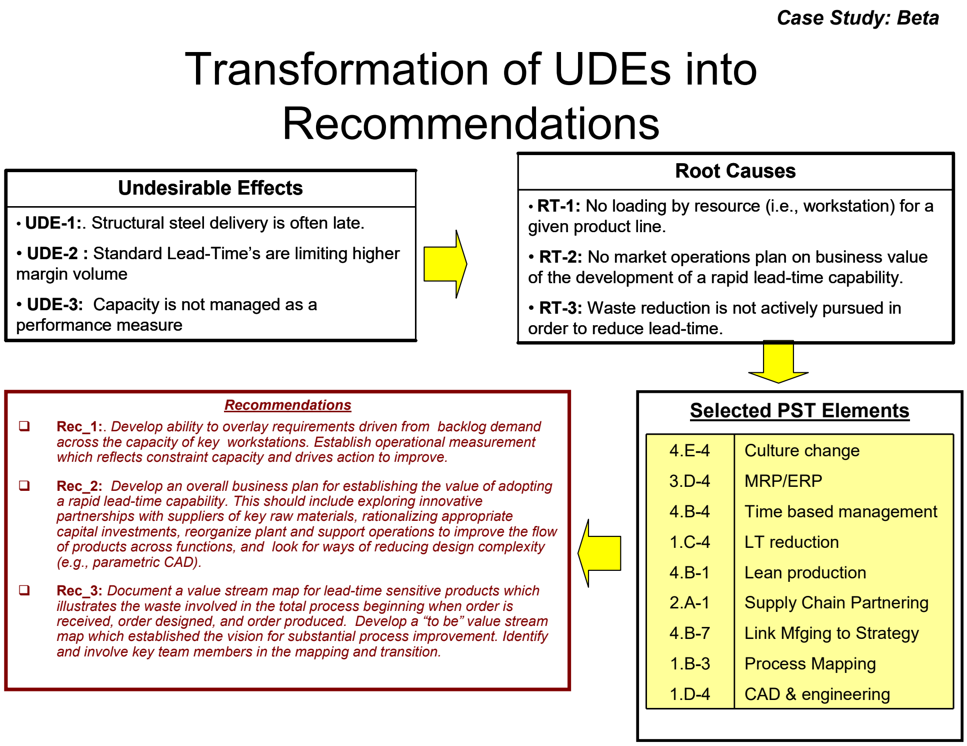


Figure 4.57 Case Beta – Transformation of UDEs into Recommendations

4.3.5 Client Receptivity

Since the Client's SMR showed much interest in the TBAM approach and it very involved at each step, the feedback from the SMR was solicited after each of the three stages. The feedback is summarized in the following figures.

Recommendation	Effectiveness *"The recommendation, if implemented, would have a substantially positive impact on the manufactring enterprise."* *Please rate each recommendation on a score of 1-5* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	Implementability *"The recommendation is practical and implementable without spending excessive time and resources."* *Please rate each recommendation on a score of 1-5* Score 1: Strongly Disagree Score 5: Strongly Agree	Overall Score
Rec_1:	4	3	7
	Important, if not critical, to develop the ability to compare demand verses capacity both for tracking improvement and targeting areas for improvement.	*Challenging to implement due to job shop type environment*	
Rec_2:	4	4	8
	Essential to take advantage of perceived market opportunities for increased profitability.	*Lots of potential - particularly in the design side. The material and purchasing side may not be realized quite as easily.*	
Rec_3:	4	4	9
	Critical to support the lead time business segment and successful improvements will also reduce overall wastes - thus increasing overall efficiencies.	*The recommendation is entirely feasible and practical. It is the only way really to attack the problem.*	

Client Feedback at the Evaluation Stage: (SMR - Plant Manager)

The biggest UDE was not previously on the radar screen… but after going through this stage it became apparent that the steel delivery is the number one issue.

The lack of key measurables became much more apparent. A couple of key measuraes are either missing or not actively managed.

The LT issue was confirmed as an opportunity.

Concern about the plant manager being present for all the meetings. The concern was that this would inhibit the group's openness. However, it did not appear as if my presence impacted the discussions. There was much value in sitting through and listening to the discussions as opposed to reading it after the fact in a report.

Client Feedback at the Diagnosis Stage: (SMR - Plant Manager)

Agree with all three of the root causes.

The logic of tying together the cause and effect linkages helps to clarify the issues.

Figure 4.58 Case Beta – Client Feedback

4.4 Case Study # 3: Gamma

4.4.1 Introduction to Gamma

Gamma is a family owned business and manufacturers precision optical components. DOD contracts represent a major customer base as are equipment fabricators for the semi-conductor industry. A wide variety of end item products are manufactured by Gamma. Major manufacturing processes include polishing, edging, shaping, and coating. In addition extremely precise measurements are required to show conformance to very tight tolerances relative such attributes as flatness, astigmatism, and wave fronts. In general customers requirements are prioritized as follows; quality, delivery, and cost.

Case Study: Gamma

August 16-17, 2007

Assessors: Clay Walden, Steve Puryear (Mississippi State University, CAVS Extension)

Scope: Focus on the on-site assessment of core functions which support the product manufacturing. On site functions include Human Resources, Accounting, Quality, Service, Manufacturing, Purchasing, and Planning.

Client Participants
Plant Manager
HR Manager
Engineering Manager
Quality and Service Manager
Planner
Purchaser
Controller

Products: Precision optical components
Prisms
Lenses

Markets
Defense
Commercial

Employees
80 employees
40 Hourly
40 Office

Figure 4.59 Overview of Gamma

4.4.2 Gamma Evaluation

The on-site survey was conducted across a one day period by two assessors. The assessment team spent 1 day comparing notes and developing the final scoring for completing the assessed fit within the MET. Next the client's was contacted for feedback and validation of Gamma's fit within the MET.

<u>4.4.2.1 Business Environment: (1.0):</u>

The business environment that Gamma competes within is described as having a moderate level of competition, generally stable with relatively few external threats, few regulations, low seasonality, and a moderate level of growth.

Gamma faces three to four major competitors, but different competitors are found within different markets. Each of the competitors possesses its preferred niche. Gamma's strength is in producing the most difficult to produce prisms and lenses. Three major DOD contractors are their primary customers, most of their business volume is defense related (i.e., 80%). Gamma's highest level of competition is on those products that have generally looser tolerances. However, about 80% of their business volume is on parts that are classified as "tight" tolerances; the competition for these is less intense.

While Gamma does not in an overall sense experience a high level of instability and external threats, there are some areas of concern. The overseas competition, in particular China, has improved their quality and is substantially cheaper. However, the overseas competition is more on the commercial than the defense related products. It should be noted that several years ago, commercial made up a significantly larger piece of their business than is currently the case. The concern is that if the defense spending reduced in the future and Gamma was forced to compete more in the commercial market this could result in competitiveness problems. An additional area of concern is that the source of all their raw materials is in Malaysia and Japan. Perhaps their biggest current threat is the availability of skilled labor and related rising labor rates from their geographical area. The area in which they operate was substantially impacted by Hurricane Katrina. Finally, the threat level overall was not deemed high primarily from the fact that they have developed a solid reputation for producing high quality product over the last 40 years and have weathered many changes in the overall business climate. One of the mitigating factors is Gamma's product has a variety of applications across industry sectors.

Gamma must adhere to typical regulations of manufacturing processes (e.g., disposal of hazardous chemicals, OSHA, lead free requirements from DOD). Also very little seasonality is present in their product demand. Gamma is currently experiencing a growing market in which everything they produce can be sold.

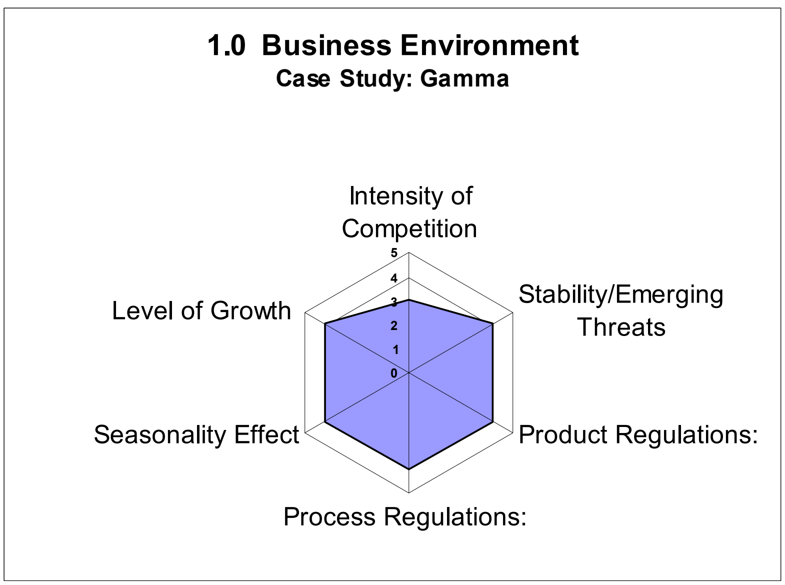


Figure 4.60 Case Gamma – 1.0 Business Environment

4.4.2.2 Leadership (2.0):

_Senior management appears to have a clear strategy regarding how they choose to compete within the business environment previously described. Senor management has focused the company on becoming exceptional at the difficult to manufacture products. Gamma fits within Porter's generic strategy of differentiated along a narrow market scope. One of their long term goals is to move from a being strictly a piece part provided into a provided of more integrated sub-assemblies. The business is family owned with three brothers managing critical aspects of the operation. While the key leaders have defined a strategy, it is not clear that the strategy has been widely deployed and embraced by a wide cross section of its employees.

Both the level and effectiveness of employee participation has been minimal in the opinion of senior management. There has not been a strong cross section of employees tackling difficult cross functional problems and developing rapid and effective counter measures to eliminate problems at their root cause. Employees tend to view their roles strictly along functional lines. Routinely problems are discussed among key employees, but rarely do follow-up investigations actually occur. Most employees are content to defend themselves as not the source and go on with their primary jobs. Finally, senior management stated that unless their employees are willing to take more risks, work better cross functionally, and take more initiative the company cannot grow.

Another area of opportunity is to effectively use some of the more highly experienced on the floor personnel to better develop more junior employees. Gamma's production environment is very technically challenging and can be highly frustrating for an extended period for new employees

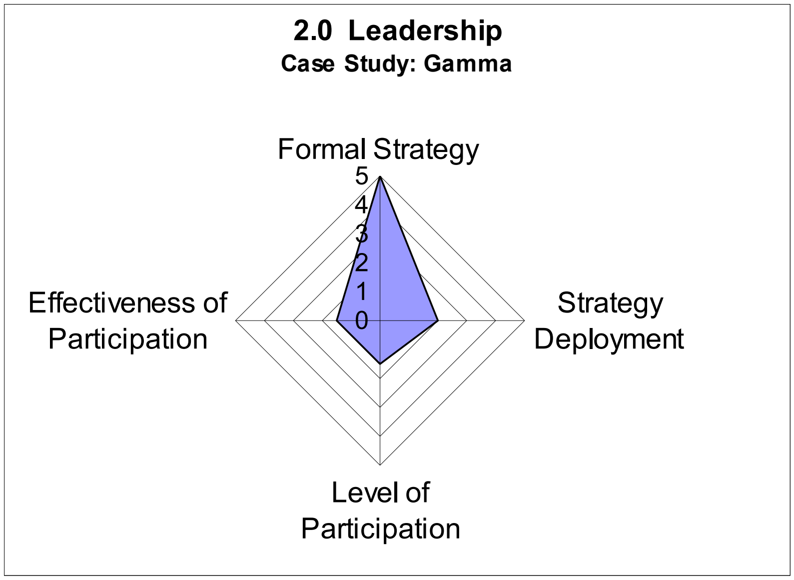


Figure 4.61 Case Gamma – 2.0 Leadership

4.4.2.3 Customer / Market Focus (3.0):

Generally, customer requirements are intentionally defined, and a feedback loop is in place that measures Gamma's ability to meet customer requirements. Also, Gamma has a clear sense of the relative priorities that customers have regarding how value is deliverd and the relative dimensions of performance.

Customer requirements are intentionally and formally communicated to production. In fact, most of the product prints are produced by Gamma's customers. No apparent problems were encountered in terms of interpreting design intent. The job requirements including prints are located in a folder which travels with the order. Gamma's feedback from customer's has been defined by their ISO 9000 system and includes returned materials, on-time delivery, and customer complaints.

Gamma has established a trademark within their industry for delivering high quality products on very difficult to manufacture products. They have historically averaged about 1%

return rate. However, these high levels of quality comes at the expense of significantly high internal scrap and re-work rates (i.e., 30-40%) and less then desirable "on-time" shipping performance.

Gamma is generally competitive on price, though at times not the low bidder. Improving on delivery performance is their biggest opportunity to make a positive difference. Senior management views customer preferences in the following order: quality is first, delivery is second, and price is third. This indicates that if delivery improves and since their quality is already a positive differentiator, Gamma has a chance to earn higher prices and greater margins.

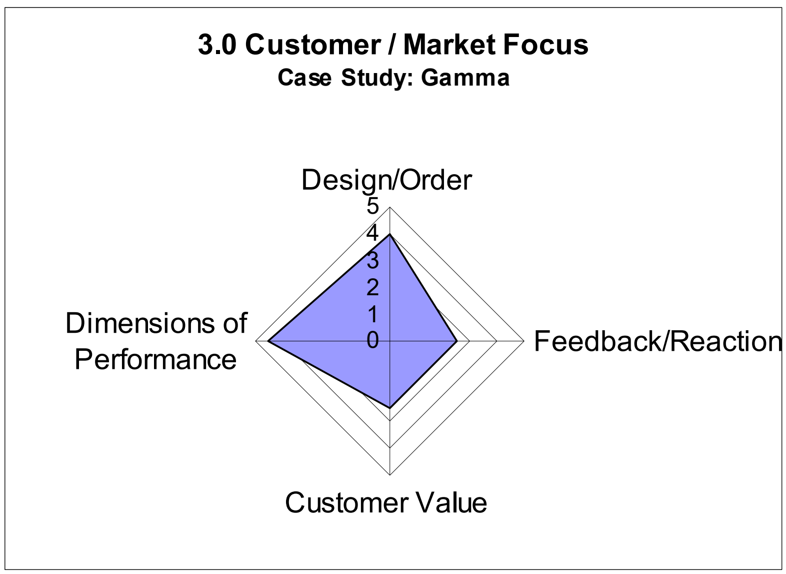


Figure 4.62 Case Gamma – 3.0 Market / Customer Focus

4.4.2.4 Information and Knowledge Management (4.0):

Generally, relevant data is available to support routine decision making. For example, a homegrown access database system can rapidly generate reports of yield, due date performance, productivity by department, workstation, and by person. However job specific information, needed to produce a quality product first time, is often not available. Therefore, there is a high reliance upon the skills and abilities of individual employees.

Job specific information is contained in a job packet that travels with the order. This packet includes notes on the conditions related to the last time the job was run, including a list of process changes implemented and their resulting impact on production. However, a high degree of experience and judgment is needed in order to properly interpret this documentation.

Overall data and information is available to support improvement efforts. This is true, despite the overall level of disappointment that senior management has relative to the effectiveness of their improvement efforts.

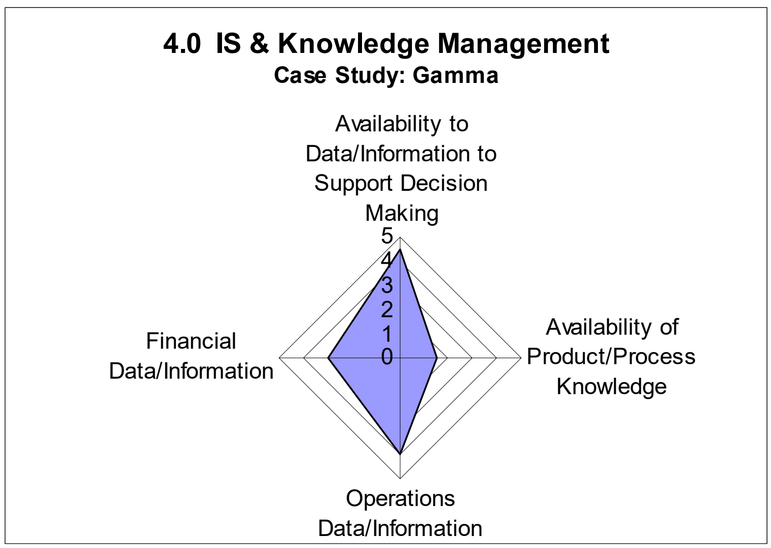


Figure 4.63 Case Gamma – 4.0 IS and Knowledge Management

4.4.2.5 Human Resources (5.0):

Overall, Gamma exhibits a relative immaturity in terms of teaming and is very functional and highly task specific in terms of focus on employees' skill development.

Clearly the level and effectiveness of team success has not reached senior managements expectations. The overall plant environment is very amicable, but little evidence of being very effective from a teaming perspective. Task skills dominate in both hiring and promotion of employees, far more than teaming qualities. Senior management has questioned its employee development model, which primarily includes people with highly effective technical skills being promoted into management. However, good technical employees, do not always make effective managers.

A great disparity exists between those operators that have developed a high skill level and those who are either just beginning or have not developed high level of skills. In Gamma's environment, it takes a relatively long time to develop people to perform at an acceptable level of performance (e.g., 6 months in milling and about 1 year in polishing).

Therefore, employee development is a challenge. Apparently, asking for assistance from other co-workers is not always common. It is not uncommon for an employee to struggle with the same job for several days or weeks. Recently they had a case where one operator took 4 weeks to only produce 75 pieces.

Gamma has identified the training issue has a clear need, but currently operate with a much lower experience and expertise level among operators than desired. One of the senior managers, when asked about the constraint to overall operations was to the overall operations answered that it was the ability to develop skilled employees on the shop floor. A training program and manual exists, but addresses primarily the basic introduction of new operators. Little formal employee development happens beyond the introductory program.

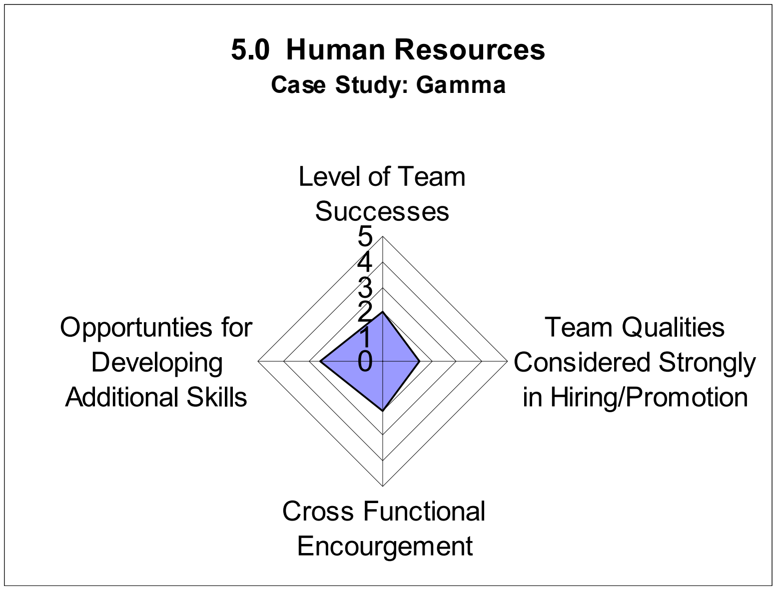


Figure 4.64 Case Gamma – 5.0 Human Resources

4.4.2.6 Development of Products and Processes (6.0):

Since Gamma is a custom contract manufacturer the development of new products is not of primary concern. However, they do take on new products, which they have never manufactured before. At any given time, about 30% of their volume falls into this category. Their ability to produce new and difficult products specified by the customer is a source of differentiation. Their effectiveness in this endeavor is indicated by a low customer return rate, but their challenge is to hit quoted lead-times. At present their customer's are more concerned with quality then ship date performance, at least up to point.

In contrast to traditional product development, process development is a key issue for Gamma. They were the first in their industry to bring in CNC milling and polishing machines into their operation. This has resulted in an advantage in terms of product quality and consistency over its competition for a period of time. Currently, the competitors have introduced CNC technologies and now Gamma is searching for the next leap in performance. According to senior management, the next area of opportunity is in terms of how they flow product (i.e., cellular), and in improving internal quality. The resulting impact of these improvements should be substantially improved delivery performance.

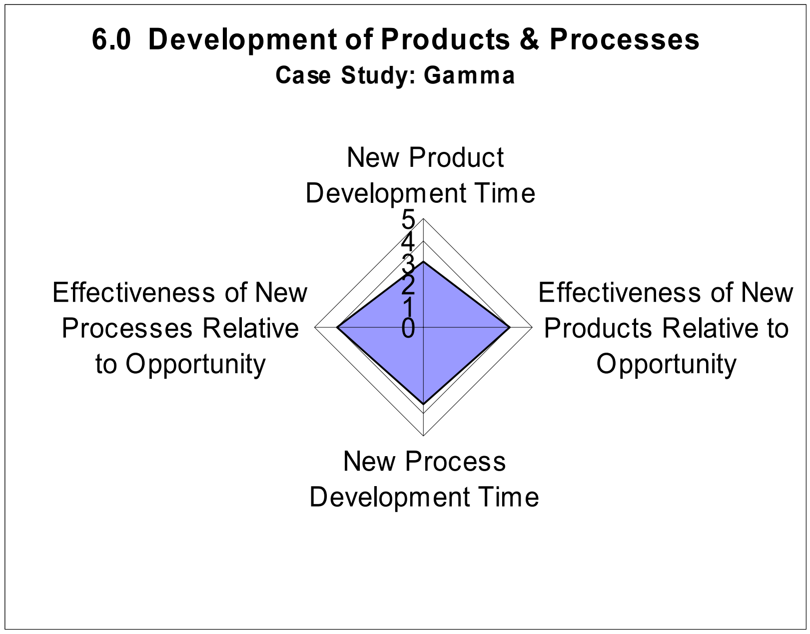


Figure 4.65 Case Gamma – 6.0 Development of Products and Processes

4.4.2.7 Product and Process Characterization (7.0):

Gamma's products are characterized generally as low volume, high mix, high level of complexity, and relatively long service lifetimes. Its processes are generally characterized as utilizing a functional layout (as opposed to cellular), high level of integration, and moderate level of capacity consumption.

Typically their products last quite long in the field. They are typically static and do really degrade over time. Therefore, unless they are damaged by an external cause, their products will outlive the system that they are embedded within. Their low volume is evidenced by it is not uncommon for order sizes as low as 50-100 pieces. There are repeat orders but typically repeat within a 6 to 18 month period. Prisms products tend to have higher volumes than lenses. Products are complex, not from the standpoint of geometry, but from exceptionally tight tolerances (e.g., flatness, radius) and tight performance requirements (e.g., light diffraction is measured in fringes on an interferometer).

Currently, the market is very strong for Gamma. They run a full day shift and selected workstations on a night shift. Overall, senior management believes the plant is the constraint to more sales (i.e., they could sale more if they could produce more with satisfactory levels of quality). However, certainly latent capacity exists, in terms of producing 40% internal reject rate.

The plant lay out is highly functional manner - dedicated milling area, polishing area, edging area, and coating area. One exception is an experimental CNC cell. In this case, the cell contains both CNC milling and CNC polishing machi9nes and both machines are manned by one highly skilled operator. Success of this pilot cell has been somewhat limited due to problems with the CNC polishing machines.

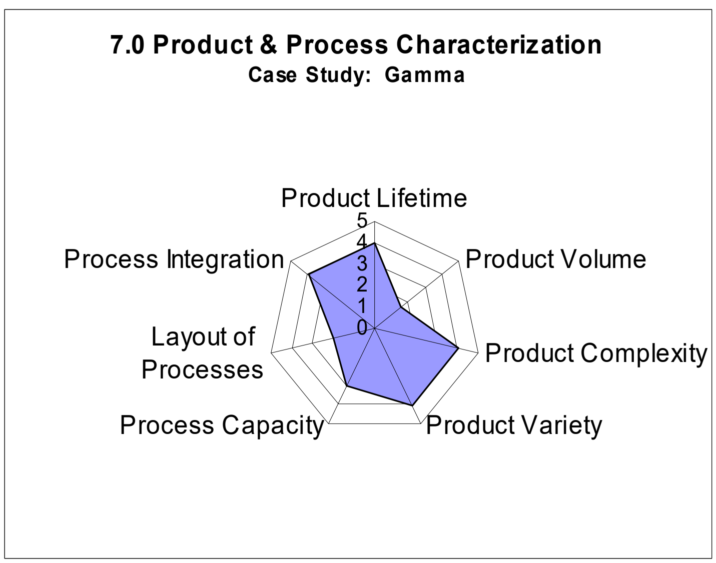


Figure 4.66 Case Gamma – 7.0 Product and Process Characteristics

4.4.2.8 Management of Extended Enterprise (8.0):

Gamma's supply chain operates with a very clear knowledge of product requirements, in terms of what is being ordered. Typically raw material specifications are provided on prints obtained from the customer. Most of their raw material purchases are driven by specific jobs. However, supplier on-time performance runs 60%-70%, which certainly impacts Gamma's ability to produce customer orders on-time. However, senior management's "gut feel" is that about two-thirds of their delivery problems is due to lack of process control within Gamma's plant, and about one-third due to problems with suppliers.

Typical order lead-time that Gamma quotes to customers is 8-10 weeks. Finished goods are kept for a few common finished good parts that have predictable repeat orders. Due to the unpredictability of their manufacturing process yields, the inventory strategy is really not well defined. Finished good inventory occurs when they get a good set-up on a part, that commonly has repeat orders, and they run more than needed for the current order. The process is very set-up intensive and once a "good" set up occurs they run as many as they can.

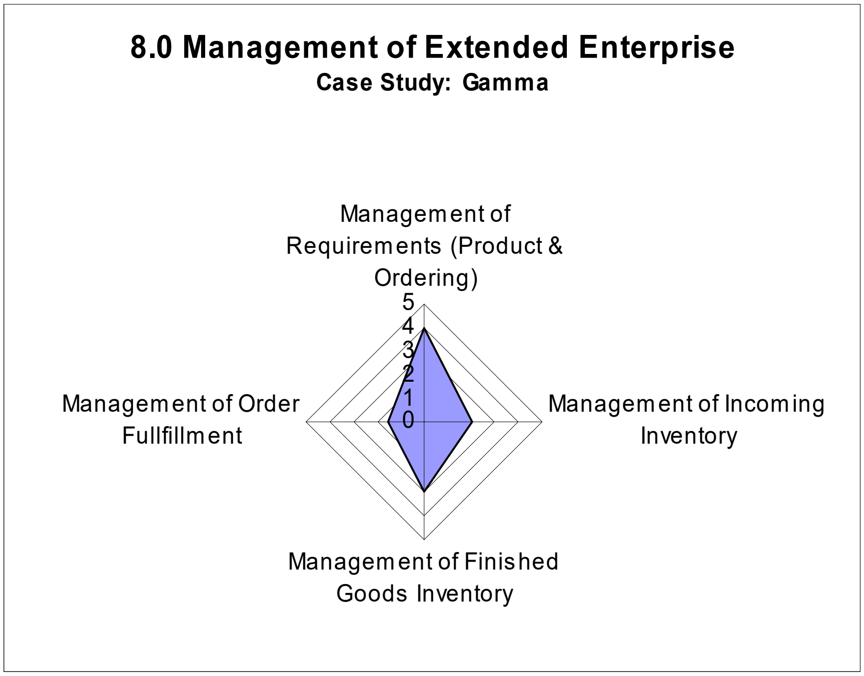


Figure 4.67 Case Gamma – 8.0 Management of Extended Enterprise

<u>4.4.2.9 Approach to Continuous Improvement (9.0):</u>

Gamma's performance measures appear to be balanced and strategically aligned. For example, they routinely measure percentage yield (by department and workstation), production (by department, workstation, and person), customer returns, and delivery date performance. Their biggest challenge is to drive improvements against these measures. In terms of process focus, it is not clear that they are pro-actively managing their constraint to improved throughput. The constraint, in the overall opinion of senior management, appears to be the ability of individual employees. Relative inexperience of shop floor employees contributes due challenges in terms of establishing internal process control conditions. They have identified their key processes from a quality standpoint, but process documentation and employee development are challenges. Also, the level of interrelationships between process steps is not clearly known. In order to address some of these challenges they Gamma has started to use some specific continuous improvement practices (e.g., Kaizen events and DOE). However, they are still early in developing and acquiring this capability. Gamma's quality system is ISO 9000 registered.

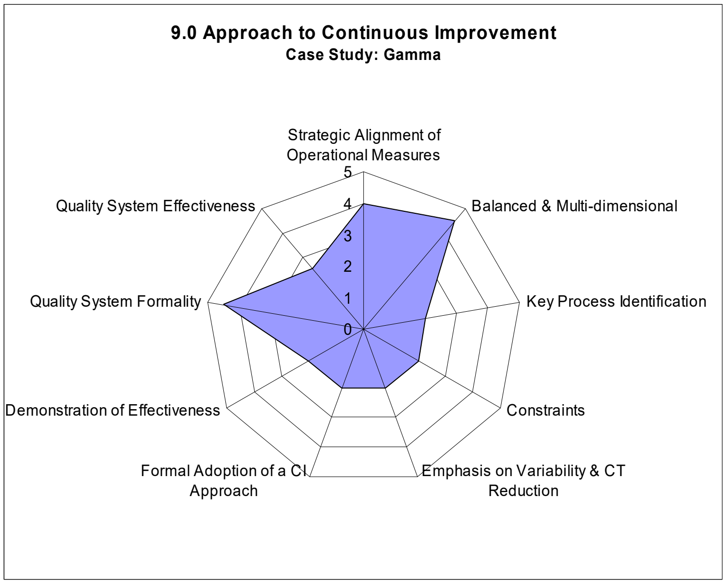


Figure 4.68 Case Gamma – 9.0 Approach to Continuous Improvement

4.4.2.10 Enterprise Financial Health (10.0):

Overall, Gamma is in a very strong position from the perspective of financial health. Access to needed capital is not restricted. In fact, capital is generally available without borrowing. Also cash flow is strong and does not impede ongoing operations.

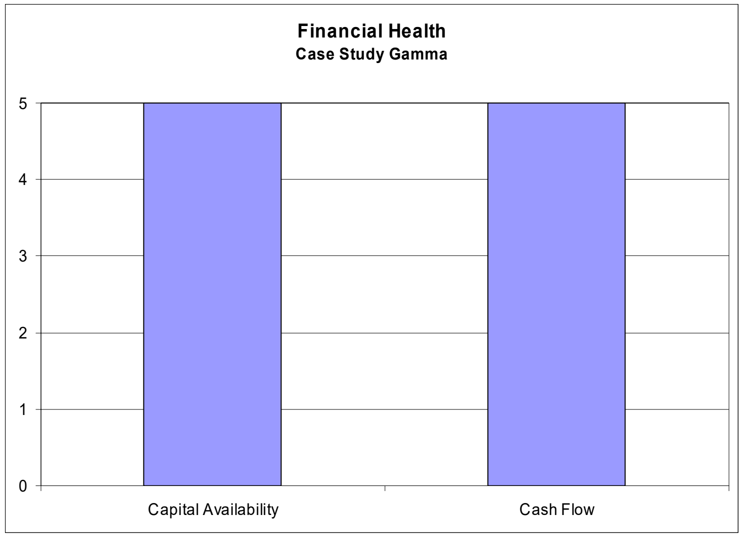


Figure 4.69 Case Gamma – 10.0 Enterprise Financial Health

4.4.2.11 Overview of Gamma's MET Fit

The following chart illustrates Gamma's score across the 10 major attributes or taxons contained within the MET. In general the biggest opportunities exist in addressing the management of extended enterprise, approach to continuous improvement, and information system and knowledge management.

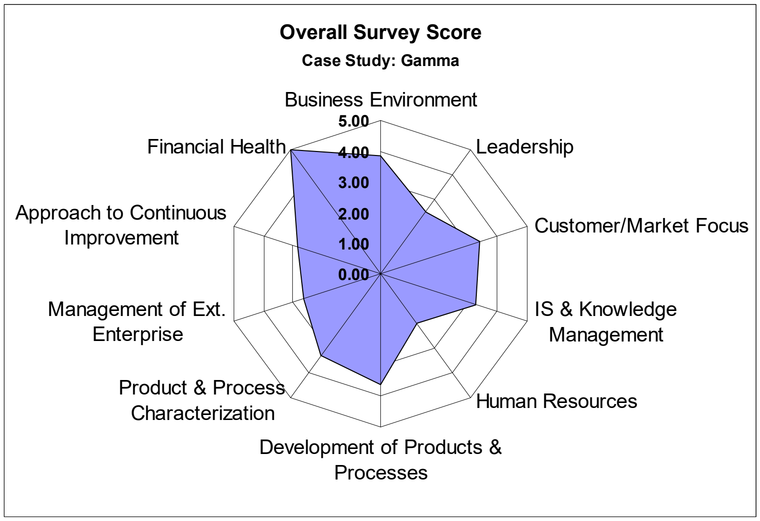


Figure 4.70 Case Gamma – Overall Fit within MET

Therefore, Gamma is classified within the Manufacturing Enterprise Taxonomy (MET) at the time of this assessment as indicated in Figure 4.71.

1.0 Business Environment			Score	Average for Category	Average for Taxon
	1.1 Competitive Environment	1.1.1 Intensity of Competition	3	3.50	3.83
		1.2.1 Stability/Emerging Threats	4		
	1.2 Regulatory Environment	1.2.1 Product Regulations:	4	4.00	
		1.2.2 Process Regulations:	4		
	1.3 Market Conditions	1.3.1 Seasonality Effect	4	4.00	
		1.3.2 Level of Growth	4		
2.0 Leadership					
	2.1 Strategic Planning & Deployment	2.1.1 Formal Strategy	5	3.50	2.50
		2.1.2 Strategy Deployment	2		
	2.2 Culture of Empowerment	2.2.1 Level of Participation	1.5	1.50	
		2.2.2 Effectiveness of Participation	1.5		
3.0 Customer / Market Focus					
	3.1 Translation of Requirements	3.1.1 Design/Order	4	3.25	3.38
		3.1.2 Feedback/Reaction	2.5		
	3.2 Positioning / Value	3.2.1 Customer Value	2.5	3.50	
		3.2.2 Dimensions of Performance	4.5		
4.0 Information System & Knowledge Management					
	4.1 Access to Information & Knowledge	4.1.1 Availability to Data/Information to Support Decision Making	4.5	3.00	3.25
		4.1.2 Availability of Product/Process Knowledge	1.5		
	4.2 Supportive of Improvement Efforts	4.2.1 Operations Data/Information	4	3.50	
		4.2.2 Financial Data/Information	3		
5.0 Human Resources					
	5.1 Maturity in Teaming	5.1.1 Level of Team Successes	2	1.75	2.00
		5.1.2 Team Qualities Considered Strongly in Hiring/Promotion	1.5		
	5.2 Employee Skill Level	5.2.1 Cross Functional Encourgement	2	2.25	
		5.2.2 Opportunties for Developing Additional Skills	2.5		
6.0 Development of Products & Processes					
	6.1 Product Development	6.1.1 New Product Development Time	3	3.50	3.63
		6.1.2 Effectiveness of New Products Relative to Opportunity	4		
	6.2 Process Development	6.2.1 New Process Development Time	3.5	3.75	
		6.2.2 Effectiveness of New Processes Relative to Opportunity	4		
7.0 Product & Process Characterization					
	7.1 Product Characterization	7.1.1 Product Lifetime	4	3.38	3.28
		7.1.2 Product Volume	1.5		
		7.1.3 Product Complexity	4		
		7.1.4 Product Variety	4		
	7.2 Process Characterization	7.2.1 Process Capacity	3	3.00	
		7.2.2 Layout of Processes	2		
		7.2.3 Process Integration	4		
	7.3 Product-Process Characterization	7.3.1 Goldratt's VAT Logical Product-Process	3	3.50	
		7.3.2 Hayes-Wheelwright Matrix	4		
8.0 Management of Extended Enterprise					
	8.1 Supply Chain Management	8.1.1 Management of Requirements (Product & Ordering)	4	3.00	2.63
		8.1.2 Management of Incoming Inventory	2		
	8.2 Distribution Chain Management	8.2.1 Management of Finished Goods Inventory	3	2.25	
		8.2.2 Management of Order Fullfillment	1.5		
9.0 Approach to Continuous Improvement					
	9.1 Performance Measures	9.1.1 Strategic Alignment of Operational Measures	4	4.25	2.83
		9.1.2 Balanced & Multi-dimensional	4.5		
	9.2 Process Focus	9.2.1 Key Process Identification	2	2.00	
		9.2.2 Constraints	2		
		9.2.3 Emphasis on Variability & CT Reduction	2		
	9.3 Use of Specific World Class Practices	9.3.1 Formal Adoption of a CI Approach	2	2.00	
		9.3.2 Demonstration of Effectiveness	2		
	9.4 Quality System	9.4.1 Formal System	4.5	3.50	
		9.4.2 Demonstration of Effectiveness	2.5		
10.0 Enterprise Financial Health					
	10.1 Capital Availability	10.1.1 Capital Availability	5	5.00	5.00
	10.2 Liquidity	10.2.1 Cash Flow	5	5.00	

Figure 4.71 Case Gamma – Detail Fit within MET

Undesirable Effects (UDEs)

The final outcome of the TBAM evaluation stage is the identification of the the client's undesirable effects (UDEs). As the following figure illustrates a total of 9 UDEs were identified during the on-site survey. The UDEs were prioritized by the client's senior management representative at the conclusion of the on-site visit. The scores associated with each UDE are shown in the figure below.

Prioritization of UDEs Identified During the MET Survey			Case: Gamma
UDE		Overall	Cumulative Percentage
1	Process Control is difficult to maintain	30	30%
2	Middle management supervisory skills underdeveloped	20	50%
3	Takes too long to develop effective shop floor employees	15	65%
4	Internal failure rate is too high (i.e., scrap and re-work)	15	*80%*
5	Frequently customer due dates are missed	10	*90%*
6	Employee turnover is too high	10	*100%*
	Total	100	

Figure 4.72 Case Gamma – UDE Prioritization

The TBAM methodology requires the top three UDEs to serve as inputs into the diagnosis phase. These UDEs are probed on during the development of the client's Current Reality Tree (CRT). The selected UDEs are shown and labeled in the figure below.

Highest Priority UDEs for Use in CRT Construction	
UDE-1	***Process Control is difficult to maintain***
UDE-2	***Middle management supervisory skills underdeveloped***
UDE-3	***Takes too long to develop effective shop floor employees***

Figure 4.73 Case Gamma – Top Three UDES for Use within the CRT

4.4.3 Gamma Diagnosis

The purpose of the diagnosis stage is to develop a logical linkage between the UDEs (i.e., symptoms) and a relatively small set of root causes. This is accomplished by the construction of the Current Reality Tree (CRT).

The CRT was constructed by picking one of the three previously identified UDEs and probing the next level of causes. Those causes are then treated as effects driven by a lower level of causes. This procedure is repeated until a large number of the UDEs appear to be related to a relatively few number of root causes.

The following narrative provides the reader with an overview of Gamma's CRT. The top three UDEs were selected as input into the CRT construction.

- UDE-1: Process Control is difficult to maintain
- UDE-2: Middle management supervisory skills are underdeveloped
- UDE-3: Takes too long to develop effective shop floor employees

Two additional UDEs were identified during the evaluation phase and time allowed for them to be logically linked into the CRT. This resulted in a more complete understanding of Gamma's root problems and their associated impacts upon a fuller range of UDEs.

- UDE-4: Internal failure rate is too high
- UDE-5: Frequently customer due dates are missed

The following is the explanation of the CRT.

The first page of the Gamma's CRT illustrates the logical connection between UDE-5, UDE-4, and UDE-1. As can be observed UDE-5 "frequently customer due dates are missed" is ultimately caused primarily by UDE-1 "process control is difficult to maintain." Therefore, UDE-1 is probed on the second page of the CRT.

The second page CRT indicates UDE-1 is caused by the entity "right factors are not consistently controlled", which is in turn caused by two major branches; entity 100 "impacts of factors are not known" (which is mapped on CRT page 3) and "production methods vary." The entity product methods vary is driven by the entity "standard work discipline not well established"; which is driven by two branches. One these branches is connected under the entity "work standards not clearly documented" and the other branch is driven from the root cause RT-1 "common understanding of production environment has not been established." The entity "work standards not clearly documented" is caused by two entities; entity 100 "impacts of factors are not known" and entity 200 "critical mass of workforce not sufficiently trained" (which is mapped on CRT page 4).

The third page CRT illustrates that entity 100 "impacts of factors not known is caused ultimately through a series of cause and effect relationships by entity 200 "critical mass of workforce not sufficiently trained" and the root RT-2 "trial and error approaches are assumed to be sufficient." The fourth page probes on entity 200 "critical mass of workforce not sufficiently trained." This entity is caused by UDE-3 "takes too long to develop effective shop floor employees." UDE-3 is ultimately driven by RT-3 "insufficient resources dedicated to training", entity 300 "those who share knowledge and skills are not consistently rewarded" (mapped on CRT page 5), and UDE-2 "middle management supervisory skills are underdeveloped" (mapped on CRT page 5). The fifth CRT page indicates that both UDE-2 and entity 300 are driven from the root RT-4 "No clearly defined path for rewarding the skilled technical person on the shop floor (i.e., beyond their work at assigned work stations)."

Case Study Gamma
Page 1

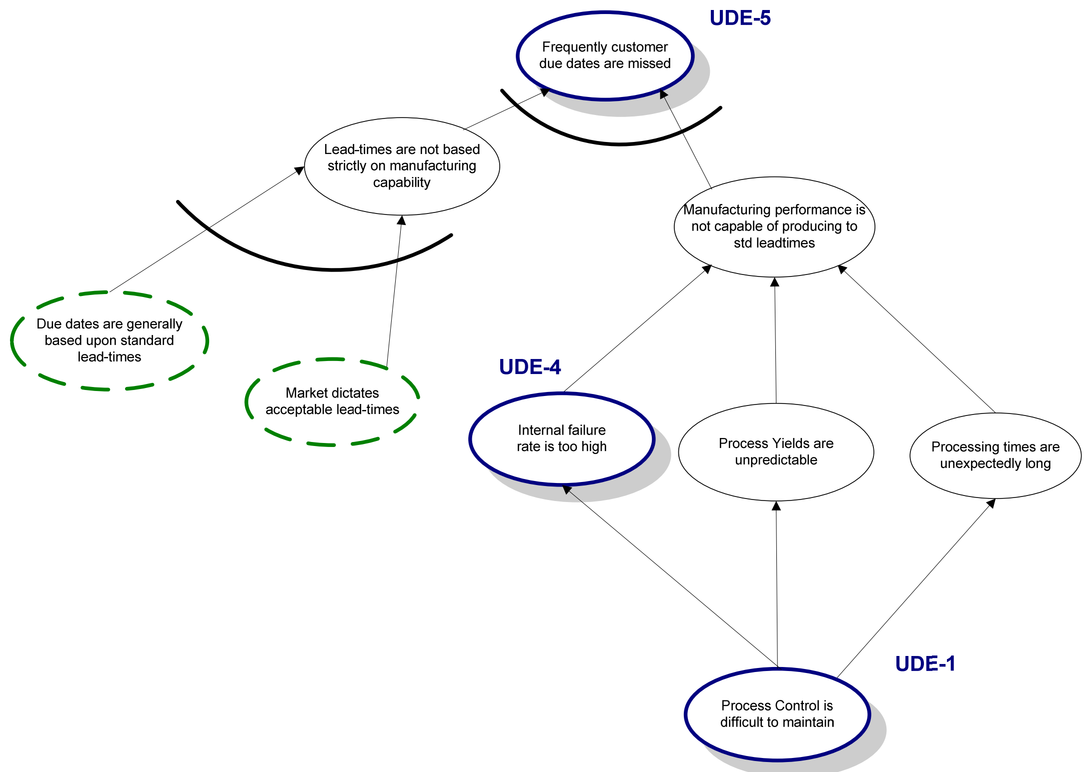


Figure 4.74 Case Gamma – CRT Page 1

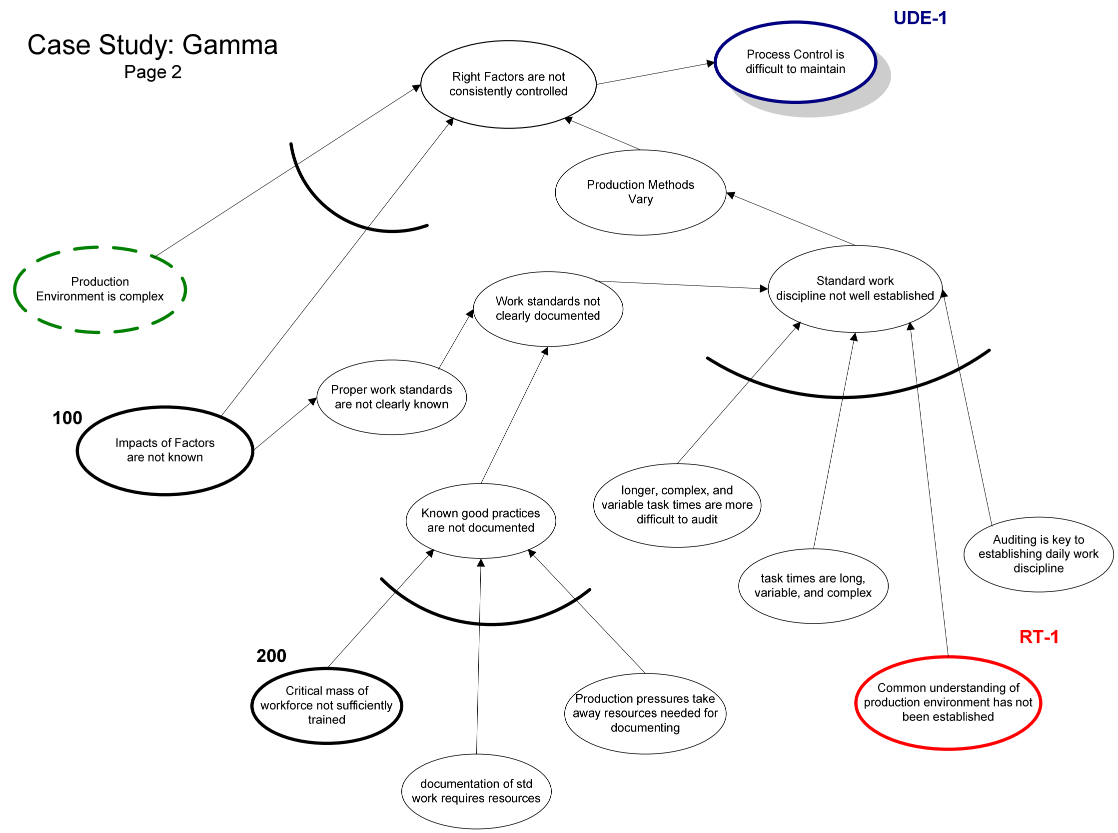


Figure 4.75 Case Gamma – CRT Page 2

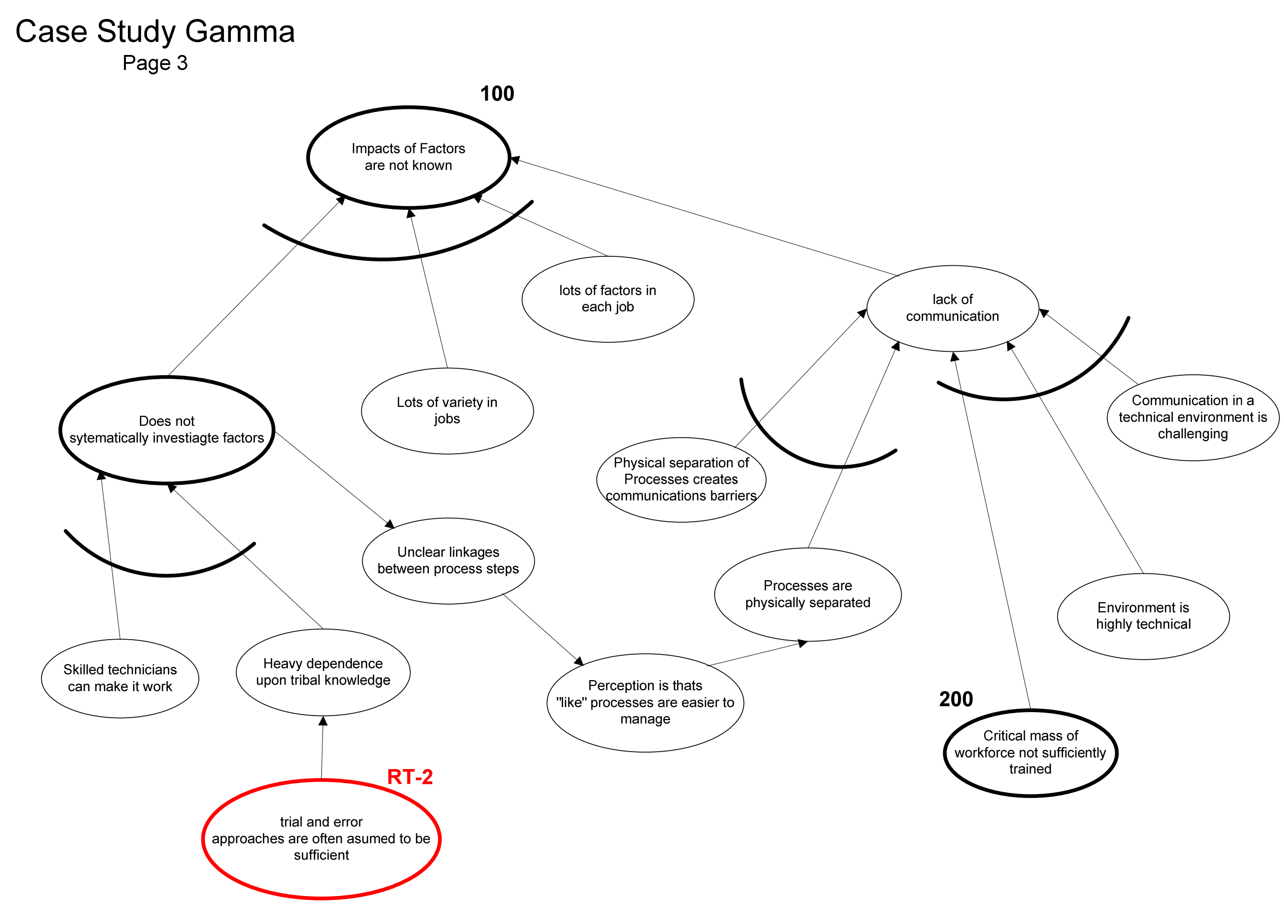


Figure 4.76 Case Gamma – CRT page 3

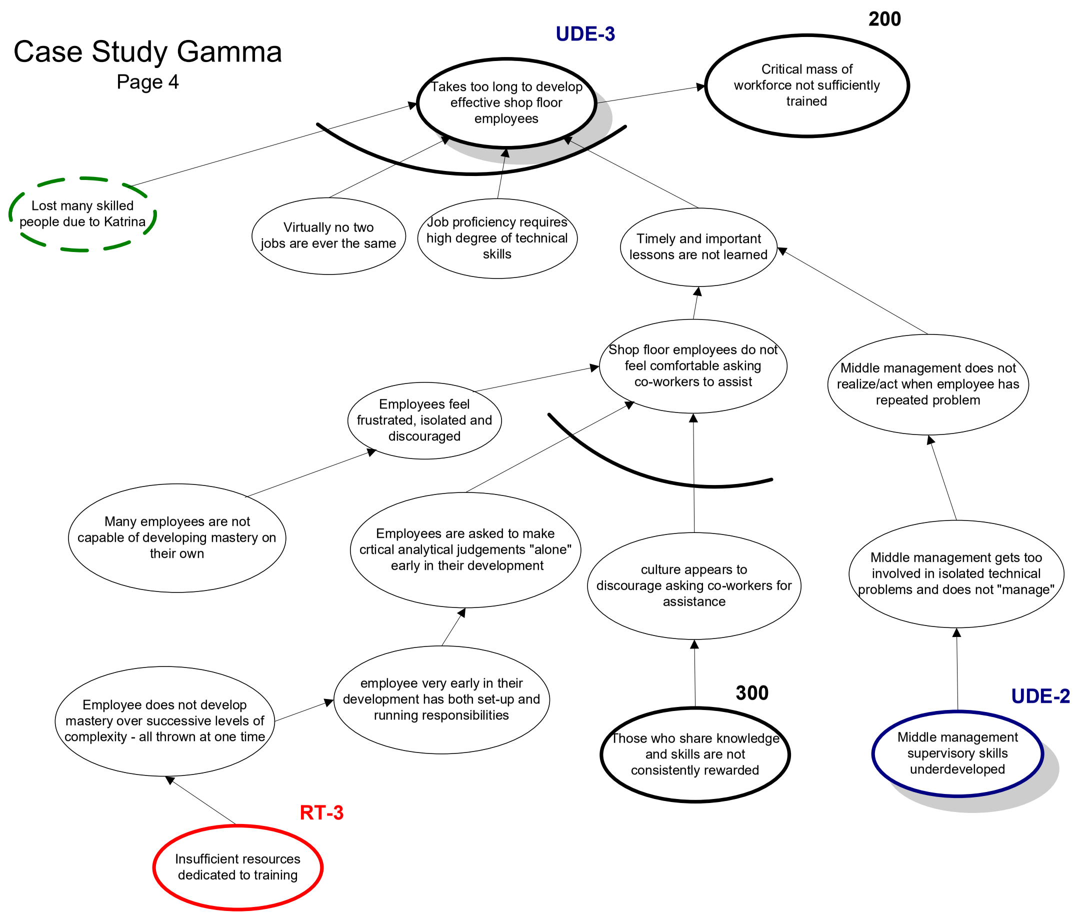


Figure 4.77 Case Gamma – CRT Page 4

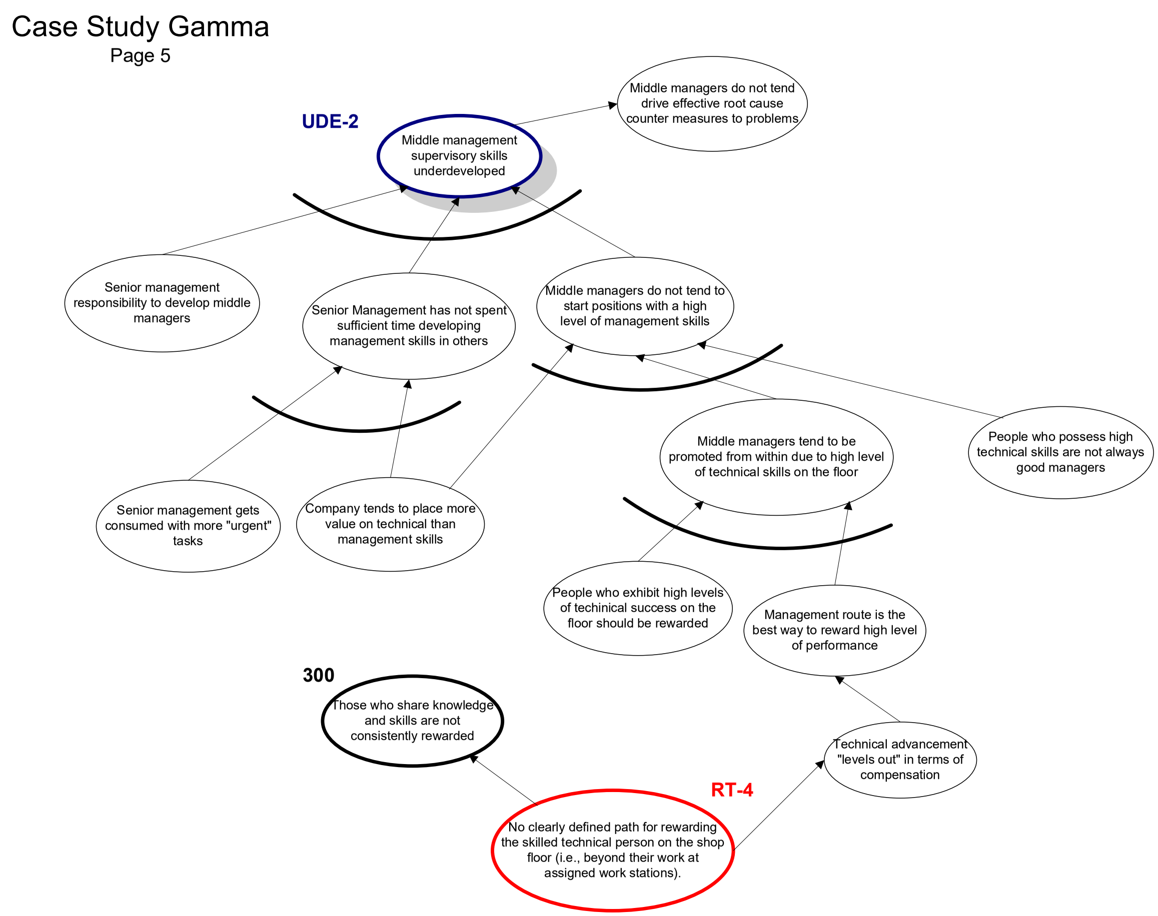


Figure 4.78 Case Gamma – CRT Page 5

The following table summarizes the results from the application of the CRT. The CRT, illustrates the logical relationship, as established by the assessment team in collaboration with the client, connecting the UDEs with root causes.

UDEs	Root Causes
• **UDE-1:**. Process Control is difficult to maintain. • **UDE-2 :** Middle management supervisory skills are underdeveloped • **UDE-3:** Takes to long to develop effective shop floor employees. • **UDE-4:** Internal failure rate is too high. • **UDE-5:** Frequently customer due dates are missed.	• **RT-1:** Common understanding of production environment has not been established. • **RT-2:** Trial and error approaches are often assumed to be sufficient. • **RT-3:** Insufficient resources dedicated to training • **RT-4:** No clearly defined path for highly skilled technical people to add value beyond their isolated work on the shop floor.

Note: There is not a one-to-one relationship between the UDEs and the four root causes. The relationships are defined by the CRT.

Figure 4.79 Case Gamma – Summary of UDEs and Root Causes

4.4.4. Gamma Prescription

The purpose of the prescription stage is to develop a set of recommendations targeted at elimination of the root causes (i.e., RT-1, RT-2, RT-3, and RT-4) identified as a result of the diagnosis stage. The first step is to identify which of the practices from the PST, are most relevant for use in development of specific recommendations.

This was accomplished by the assessment team multi-voting across the set of root causes. The PST element multi-votes were summed across each of the root causes in order to provide a composite score. These total scores for those practices receiving votes are shown in the Table below. The rule of thumb is to select a subset of prescriptions that account for approximately 80% of the total score. In general, these are the best practices that are most relevant to the assessment of Gamma. In the case of Gamma, this procedure resulted in identifying a subset of 15 out of the total 91 PST elements. These 15 best practices from the PST were deemed as the most relevant to the core problems. In general, these are the most relevant set of best practices used to guide the development of the set of recommendations. The result of this process is summarized in the Figure below.

Case Study: Gamma

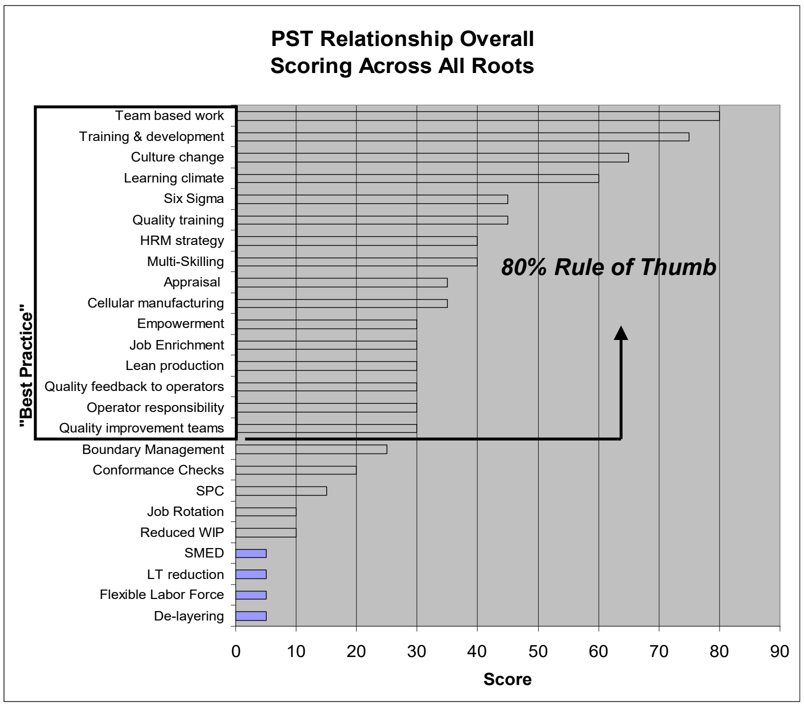


Figure 4.80 Case Gamma – PST Elements Scored Across All Roots

This collective set of prescriptions was used for comparative purposes with the review panel. This allowed for a measure of validity by comparing the overall level of agreement between an objective third party (i.e., review panel) and the decisions of the assessment team in the field.

The next step in terms of moving toward the development of recommendations was an analysis of the selected PST elements for each of the root causes (i.e., RT-1, RT-2, RT-3, RT-4).

For this case study, Recommendation #1 was developed to address RT-1, Recommendation #2 targets RT-2, and Recommendation #3 attacks both RT-3 and RT-4.

Recommendation #1 addresses the root labeled "common understanding of production environment has not been established" (i.e., RT-1). In the formulation of the recommendation it is important to refer to the context within the CRT which is associated with RT-1. By observation of CRT (Figure XX, CRT page 2), it is seen that RT-1 is primarily associated with driving by the following entities.

- "standard work discipline not well established",
- "production methods vary",
- "right factors are not consistently controlled."

The selection from the PST resulted in the following elements as most relevant to RT-1.

- 4.B-1 Lean Production
- 4.E-4 Culture Change
- 1.E-4 Appraisal
- 3.A-2 Team Based Work
- 4.E-5 Learning Climate

It is within this context that the Recommendation #1 (essentially the need to develop a visual plant management system) was developed follows.

> *Recommendation #1:* Establish a visual management program on the floor so that non-preferred conditions/methods are rapidly detected and corrected and preferred conditions/methods are clearly illustrated. This includes the use of such tools as 5S, one-point lessons, and "andon" indicators at the workstation to indicate current performance status in terms of both quality and throughput [e.g., red – immediate attention, yellow-danger, green-proceed]. Establish regular audit program to ensure compliance and

effectiveness. Publicly track audit results so that progress toward a more visual shop floor is tracked more objectively.

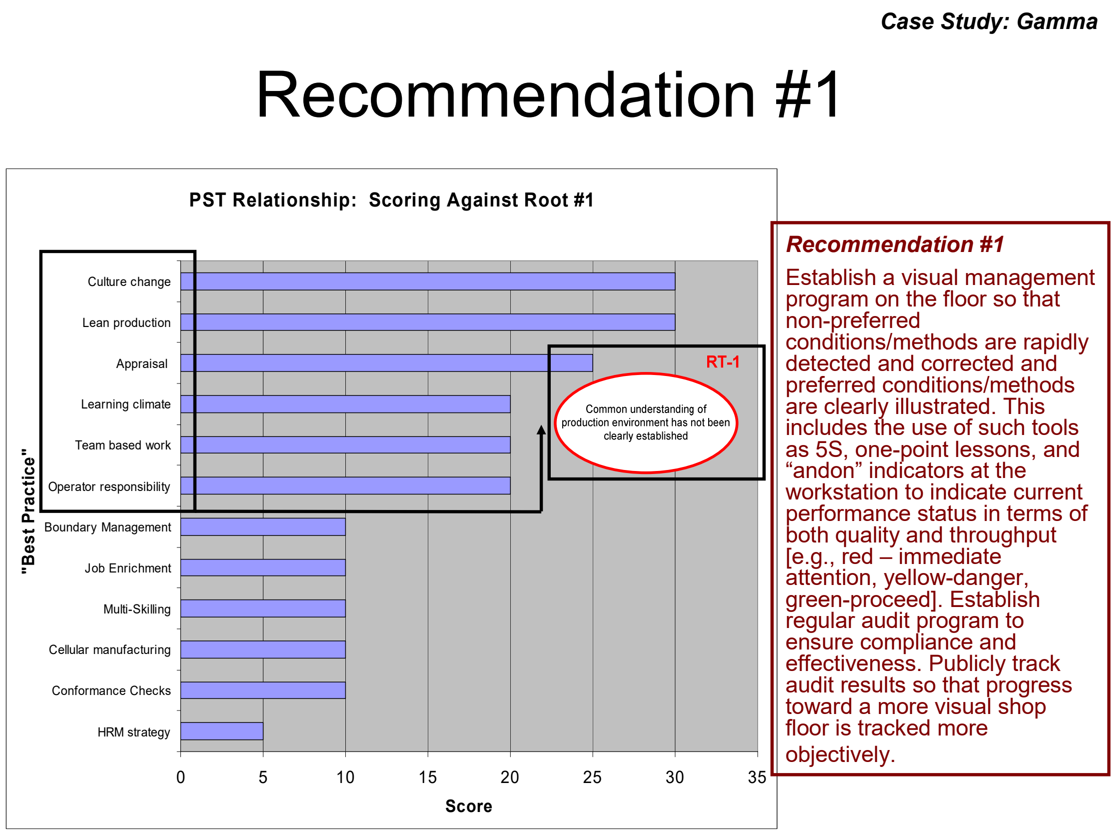


Figure 4.81 Case Gamma – Development of Recommendation #1

The following Figure is provided to show how the selected PST "best practice" elements map into recommendation #1. Based on careful review of recommendation #1, there is a strong connection with five out of these six PST "best practice" elements

Linking PST Elements to Recommendation #1

Recommendation #1

Establish a visual management program **(4.B-1, 4.E-4)** on the floor so that non-preferred conditions/methods are rapidly detected **(1.E-4)** and corrected and preferred conditions/methods are clearly illustrated. This includes the use of such tools as 5S **(4.B-1)** one-point lessons **(4.E-5),** and "andon" indicators **(4.B-1)** at the workstation to indicate current performance status in terms of both quality and throughput [e.g., red – immediate attention, yellow-danger, green-proceed]. Establish regular audit program **(1.E-4)** to ensure compliance and effectiveness. Publicly track audit results so that progress toward a more visual shop floor is tracked **(3.A-2)** more objectively.

Prioritized PST Elements for Root #1

Ref #	PST Element
4.B-1	Lean production
4.E-4	Culture change
1.E-4	Appraisal
3.A-2	Operator responsibility
3.E-2	Team based work
4.E-5	Learning climate

Figure 4.82 Case Gamma – Linking PST Elements to Recommendation #1

A similar process was conducted for the development of the second and third recommendation. The only difference was the assessment team deemed it appropriate to group RT-3 and RT-4 during the development of the third recommendation.

Recommendation #2 was developed to address the root labeled "trial and error approaches are assumed to be sufficient" (i.e., RT-2). The context surrounding RT-2 includes the following entities (refer to Figure … CRT page 3).

- "Does not systematically investigate factors"
- "Impacts of key factors are not known"
- "Proper work standards are not clearly known"
- "Right factors are not consistently controlled

The selection from the PST revealed the following best practices were most relevant to RT-2.

- 4.D-5 Six Sigma
- 3.A-1 Quality improvement teams

- 3.A-3 Quality feedback to operators
- 1.E-5 Training and development
- 3.E-2 Team based work
- 1.A-2 SPC
- 3.C-3 Cellular Manufacturing
- 4.E-5 Learning Climate.

It is within this context that Recommendation #2 was formulated as follows.

> *Recommendation #2:* Accelerate transition away from functional layout toward a cellular layout in order to enhance communications between processes. Continue to apply DOE and other statistical tools to shed light on the effect of processes (e.g., milling) on downstream processes (e.g., polishing). Regularly review capability of the measurement system in terms of repeatability and reproducibility.

This approach is summarized in the following Figure.

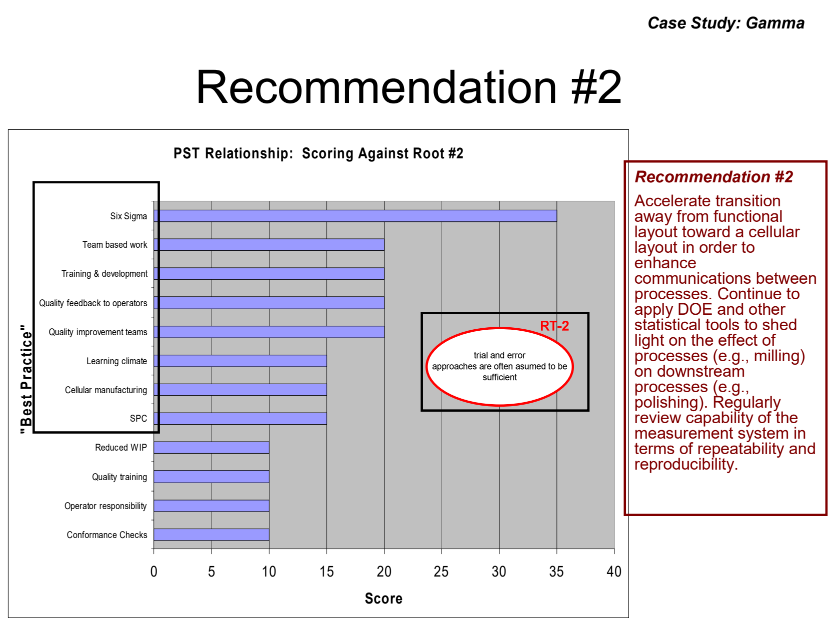


Figure 4.83   Case Gamma – Development of Recommendation #2

Based upon review of recommendation #2, the selected PST best practice elements are mapped into recommendation #2 as illustrated in the following Figure.

Case Study: Gamma

Linking PST Elements to Recommendation #2

Recommendation #2

Accelerate transition away from functional layout toward a cellular layout **(3.C-3)** in order to enhance communications between processes **(3.A-1, 3.A-3, 3.E-2).** Continue to apply DOE and other statistical tools **(4.D-5, 1.E-5)** to shed light **(4.E-5)** on the effect of processes (e.g., milling) on downstream processes (e.g., polishing). Regularly review capability of the measurement system in terms of repeatability and reproducibility **(4.D-5).**

Prioritized PST Elements for Root #2

Ref #	PST Element
4.D-5	Six Sigma
3.A-1	Quality improvement teams
3.A-3	Quality feedback to operators
1.E-5	Training & development
3.E-2	Team based work
1.A-2	SPC
3.C-3	Cellular manufacturing
4.E-5	Learning climate

Figure 4.84 Case Gamma – Linking PST Elements to Recommendation #2

Recommendation #3 was developed to address two roots (RT-3 and RT-4). These roots are labeled “insufficient resources dedicated to training” (i.e., RT-3) and “no clearly defined path for rewarding the skilled technical person on the shop floor – beyond their work at assigned workstations” (i.e., RT-4). The context from the CRT indicated the following entities were driven by the aforementioned roots (reference Figures … CRT pages 4 and 5).

- “employees do not develop mastery over successive levels of complexity – all are throne at one time”
- “employees are asked to make critical analytical judgments alone early in their development.”
- “takes too long to develop effective shop floor employees (UDE-3)

- “those who share knowledge and skills are not consistently rewarded”
- “middle managers do not start positions with a high level of management skills”
- “management supervisory skills are underdeveloped (UDE-2).

The selection from the PST revealed the following best practices were most relevant to RT-3 and RT-4.

- 1.E-5 Training and development
- 3.E-2 Team based work
- 3.A-4 Quality Training
- 4.E-1 HRM Strategy
- 4.E-4 Culture change
- 1.E-2 Multi-skilling
- 4.E-2 Empowerment
- 4.E-5 Learning climate
- 3.E-3 Job Enrichment
- 3.E-4 Boundary Management

It is within this context that Recommendation #3 was formulated as follows.

Recommendation #3: Develop a technical career path which encourages those that have attained a high level of mastery to share, mentor, and develop others. This provides a career growth opportunity outside of management in terms of mentoring other employees in developing greater skills. Establish “stair step” milestones so that employees can achieve intermediate levels of success. Consider classifying employees in terms of their ability to handle jobs of low-medium-high levels of difficulty and in terms of their skills at performing set-ups and process monitoring. Publicly track development of employees across development benchmarks.

This procedure is summarized in the following Figure.

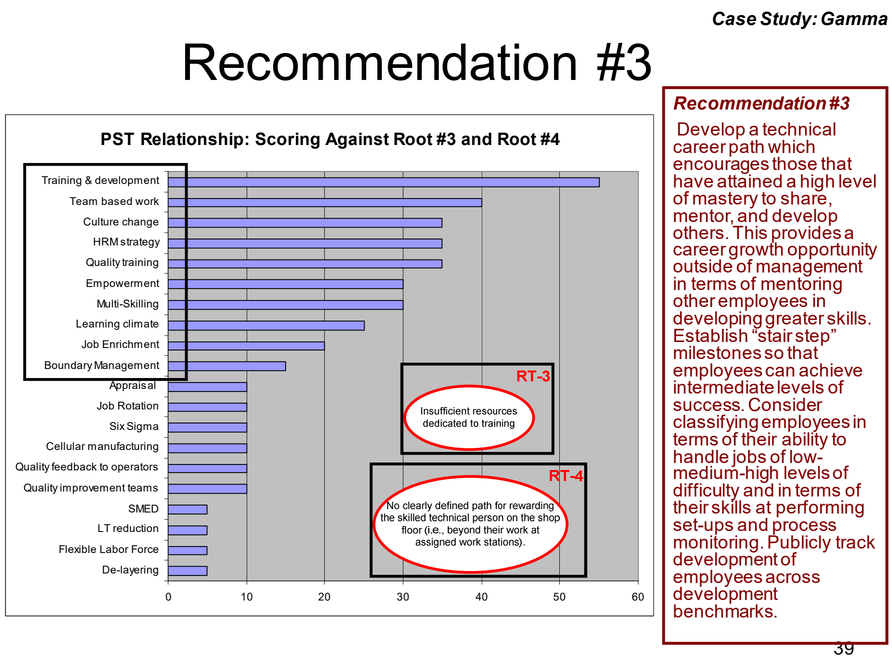


Figure 4.85 Case Gamma – Development of Recommendation #3

Based upon review of recommendation #3, the selected PST best practice elements are mapped into recommendation #3 as illustrated in Figure 4.85

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Case Study: Gamma

Linking PST Elements to Recommendation #3

Recommendation #3

Develop a technical career path **(4.E-1, 3.E-3)** which encourages those that have attained a high level of mastery to share, mentor, and develop others **(1.E-5, 3.E-2).** This provides a career growth opportunity outside of management in terms of mentoring other employees in developing greater skills **(1.E-2, 3.A-4).** Establish "stair step" milestones so that employees can achieve intermediate levels of success ***(4.E-5)***. Consider classifying employees in terms of their ability to handle jobs of low-medium-high levels of difficulty and in terms of their skills at performing set-ups and process monitoring. Publicly track development of employees across development benchmarks **(4.E-4)**.

Prioritized PST Elements for Root #3, #4

Ref #	Best Practice
1.E-5	Training & development
3.E-2	Team based work
3.A-4	Quality training
4.E-1	HRM strategy
4.E-4	Culture change
1.E-2	Multi-Skilling
4.E-2	Empowerment
4.E-5	Learning climate
3.E-3	Job Enrichment
3.E-4	Boundary Management

Figure 4.86 Case Gamma – Linking PST Elements to Recommendation #3

The overall prescription stage, for the Gamma case study is outlined in the Figure below. In the TBAM methodology the prescription stage translates the of UDEs into specifically crafted recommendations through the use of the Production Systems Taxonomy (PST) of best practices.

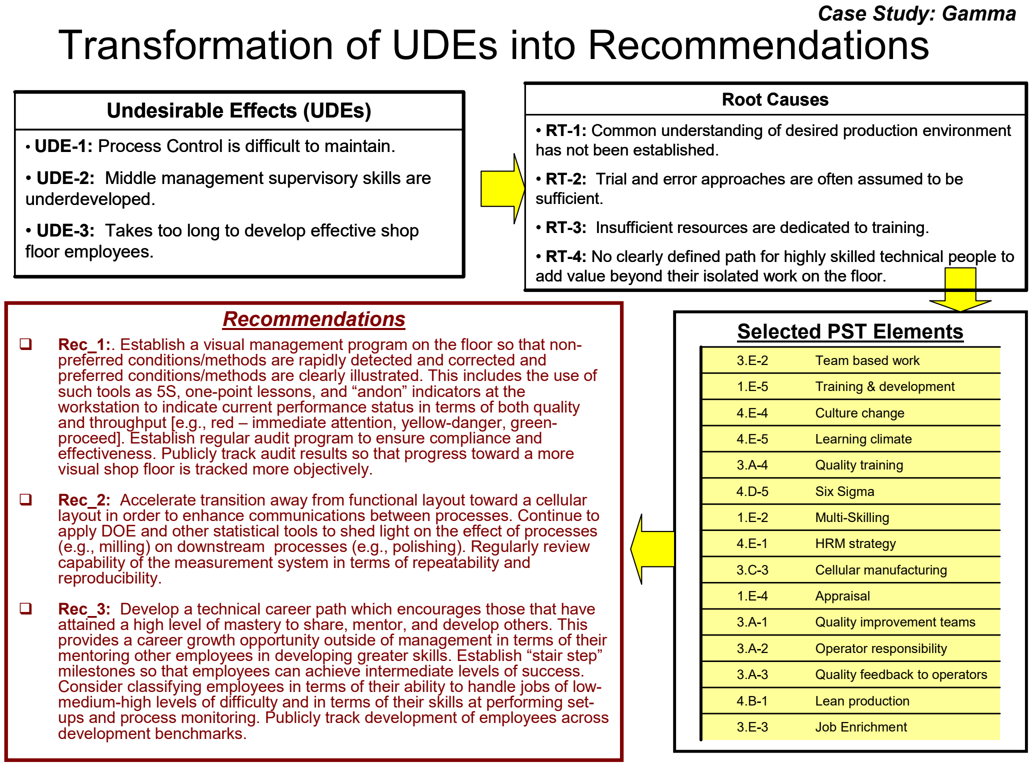

Figure 4.87 Case Gamma – Transformation of UDEs into Recommendations

4.4.5 Client Receptivity

The client's feedback to the overall methodology and to resulting recommendations is summarized in the following Figure. The client's SMR rated each recommendation on a scale of one (strong disagreement) to five (strong agreement) in terms of both effectiveness and implementability. In general, the client was particularly supportive of recommendations #2 and #3 in terms of their effectiveness and implementability. While the client was generally favorable about the effectiveness of recommendation number #1, the implementability of this recommendation was not as clear. It should be noted that recommendation # 1, relied more heavily on lean "jargon." Perhaps this recommendation could have been written more clearly, particularly since the client is new the lean manufacturing concepts.

TBAM Feedback: Client Receptivity
Client Gamma

Recommendation	**Effectiveness** *"The recommendation, if implemented, would have a substantially positive impact on the manufactring enterprise."* *Please rate each recommendation on a score of 1-5* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	**Implementability** *"The recommendation is practical and implementable without spending excessive time and resources."* *Please rate each recommendation on a score of 1-5* Score 1: Strongly Disagree Score 5: Strongly Agree	**Overall Score**
Rec_1:	4	3	7
Rec_2:	5	5	10
Rec_3:	5	5	10

General Comments
The assessment brought some things into focus and helped establish a stronger sense of the priorities. Overall this was worth the investment of time and resulted in recommendations which are both helpful and implementable. However, much additional work and thought is required in order to achieve desired results.
Would like to see a tighter connection between the best practice elements and the recommendations.

Figure 4.88 Case Gamma – Client Feedback

4.5 Case Study Review

The following section reviews the case study work from a couple of different perspectives. The first aspect of the review is in terms of the key questions of interest introduced prior to the case study narrative at the beginning of this chapter. These questions include the identification of specific ways the methodology was changed as a result of the case study piloting activity. In addition, specific critiques were made of the TBAM process. These critiques are organized in terms of the three stages of the assessment: evaluation, diagnosis, and prescription.

4.5.1 Responses to Questions of Interest Regarding the TBAM Methodology

Prior to the case studies, a series of questions were identified for which it was hoped to gain insight about based on the case studies. These questions are listed and answered as follows.

- How much time is required from both the client and the assessment team's standpoint to complete the TBAM process?
  - In the case of Alpha, the assessment team spent 48 hours to complete the methodology. This included extensive interactions with the client (three follow-up visits on site) after the on-site 1.5 day evaluation.
  - In the case of Beta, the assessment team spent about 28 hours to complete the TBAM methodology. A more moderate amount of follow up was required for Beta; primarily need focused on the final construction of the CRT.
  - In the case of Gamma, the assessment team spent a total of 20 hours to complete the TBAM methodology. Only one follow up visit was needed to validate the CRT and to deliver the recommendations.
  - Across all three cases there appeared to be learning curve effect as the assessors became more familiar with the methodology.
- What changes should be made to the TBAM methodology during the case study and why? Also if these changes were implemented what were their effects?
  - Beta's SMR participated in the multi-vote due to his broad familiarity, background, and experience the best practices which comprise the PST. This was not done for the Alpha and Gamma cases. This worked out very effectively for Beta and appeared to positively impact buy-in of the recommendations.
  - For Beta the client feedback was obtained on three different occasions, after the conclusion of each of the three major TBAM stages (evaluation, diagnosis,

prescription). This was enabled because of the high level of involvement that of Beta's SMR.

- The recommendations for Beta and Gamma were developed explicitly based on each individual root's multi-vote. As opposed to the Alpha case where the individual root's multi-vote was conducted, but the final recommendation set were derived from the total set of "selected best practices." In the opinion of the assessment team the approach used with Beta and Gamma worked better, from the perspective of more specific and focused selected PST "best practice" elements.
- The actual on site survey using the MET was conducted somewhat differently in each case. In the case of Alpha, typically 4-6 people were in the room at any one time, which slowed down the survey but enabled the capture of multiple perspectives. For case Beta, the SMR was present for the entire on-site assessment and rotated two different employees each time to cover selected areas of the survey. In this situation, less interaction and debate was observed. In the case of Gamma, the SMR was less involved than was the case in Alpha and Beta. It appears as if allowing for some freedom in some of the details might be good from the standpoint of using the methodology in different environments. However, there is clearly room for improvement in terms of obtaining a more consistent and clearer picture of the client.
- Consideration should be given to ensuring that multiple perspectives are included during the on-site survey. This should include cross functional, hierarchical, and shop floor employee perspective. In all the case studies the primary interactions were with senior management, senior staff, and middle management.

Consideration should be given to more of a 360 degree perspective of the key issues within the MET based survey.

- Were there any difficulties associated with using the anchor scoring defined within the MET based survey? If so, what changes should be considered?
  - The anchors for some of the MET elements under taxon 1.0 Business Environment were changed in order for the scales to more consistently reflect the "business environment" dimension. This was found when it was found that the client had trouble interpreting the radar graphs that visually indicate the fit of the company within the MET. The change was made so that a high value across each of the "business environment" elements reflects a positive business environment. Correspondingly a low value across the elements score illustrates a challenging environment.
    - For section 1.1.1 the anchor "few competitors" went from a value of "1" to "5" and the anchor "numerous competitors" went from "5" to "1."
    - For section 1.2.1 the anchor "few regulations" went from a value of "5" to "1" and "many regulations" went from "1" to "5."
    - For section 1.2.1 the anchor "few regulations" went from a value of "5" to "1" and "many regulations" went from "1" to "5."
    - For section 1.3.1 the anchor "heavy seasonality" went from "5" to "1" and "no seasonality" went from "1" to "5"
- Were there any challenges encountered during the pilot that might become barriers to other possible client's use of the methodology? Any suggestions about overcoming these barriers?

- The CRT proved to be the most time consuming, challenging, yet perhaps most critical aspect of the methodology. The key point was the buy-in regarding the root causes solicited from the CRT. Once the CRT was validated, the subsequent selection of PST elements and the development of specific recommendations were very straight forward. The concern is that some client's senior management representatives will not have the tolerance to engage with the assessors on the tree validation. This is more of a concern, the longer it takes to develop the CRT. However, there appeared to be a learning curve effect, resulting in the third case (i.e., Gamma) taking significantly less time than first case (i.e., Alpha). Perhaps in later versions of TBAM generic trees can be selected in order to reduce
- It was determined during case study Beta that writing the narrative after the on-site survey prior to constructing the CRT appeared to have a positive effect on the ability to develop the CRT. This was an unintended consequence of deciding to write the evaluation narrative within two days of completing the on-site survey of case Beta. Approximate time reduced from 22 hours to construct and validate the CRT to about 8 hours.[164]
- The radar graphs were somewhat confusing to participants from Alpha, but seemed to be more intuitively appealing for Beta and Gamma participants. This may be a consequence of the learning curve effect of using the methodology.

- Does the assessment team have enough intuition about the client after the on-site evaluation stage is completed to construct a reasonable CRT?

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[164] See article by Ford, Evans, and Matthews (2004) suggesting the use of "memoing" as a research tool for use within operations management case studies.

- The development of the CRT for Alpha was much more difficult than for Beta or Gamma. The initial CRT developed by the assessment team for Alpha was very crude; its primary purpose was to instruct the participants on the mechanics of CRT construction.
- The initial CRT for Beta was much better received by the SMR and resulted in only minor "tweaking" of the tree. The CRT for Gamma was accepted as valid by the client's SMR the first time it was presented.
- As a result of all three case studies, it is noted that the key issue for the assessment team during the evaluation stage is to probe and listen for UDEs during the on-site survey period. Then to probe discussions surrounding these UDEs so that the team gets a better understanding as to the underlying relationships that drive the apparent problems. Therefore, the notes supporting the ratings given to each element were actually more critical to the TBAM methodology than was the rating itself.

- How much of the client's time was required to validate the CRT?
  - For case study Alpha about 6 hours of the client's time was needed for collaboration on the CRT. Clearly, this level of engagement of a tool like the CRT limits the domain of manufacturers that would have the tolerance for working through the methodology. Fortunately, the SMR for Alpha was very tolerant and eager to engage the process.
  - For case Beta and Gamma, the client's time requirements dropped to approximately 2 hours.

- Did any problems surface during the selection of PST elements in relationship to root causes? If so, then what are the suggestions for refining either the PST or the element selection approach?
    - The selection approach in terms of the use of multi-voting, using the 80% rule worked fine. The difficulty was in using the Bolden's modified taxonomy as the PST. This PST has a total of 91 elements, many of which are overlapping, and not clearly distinguished from each other. This despite the fact that these best practices are defined. It is just a very long list to evaluate across.
    - On the positive side, the lengthy nature of the PST elements actually serves as an effective checklist. The multi-voting was conducted separately for each root cause. It was recognized that the PST elements are not so much the solution from which to pick from but serve as guides from which to craft recommendations.
- What areas of future research should be focused on in order to reduce the resource level and timeframe for conducting the assessment?
    - Certainly the proficiency of using the overall instrument appears to increase over time which in turn results reduces the total team.
    - There appears to be an interesting relationship between totally different company's UDEs. This was discovered when a prototype CRT was shown to Alpha for the intention of assisting them with learning the CRT. This CRT was constructed by the principal investigator for a totally different company in a totally different industry. It is suspected that over time, a library of generic CRT's could be constructed, which may reduce the CRT construction time.

4.5.2 Specific Critiques of Methodology Arising from Case Studies

Overall, the biggest critique of the methodology based on the work of the case studies was the length of time that it took to complete the assessment. The first case study Alpha took the longest time to complete, 48 hours of time by the assessment team. This included an elapsed time of approximately 7 weeks. The ultimate goal is to complete the entire assessment within one week. However, case studies Beta and Gamma took considerably less time and overall effort to complete the assessment. Case Beta took 28 hours of time to complete the assessment and case Gamma took only 20 hours to complete. Also both Gamma and Beta took an elapsed time of 2 weeks.

In each of the case studies the most challenging and difficult step was to complete the current reality tree. For the case Alpha this took several iterations before the client was comfortable and the need for multiple iterations drove the longer elapsed time. Fewer iterations of the CRT were required for both the Beta and Gamma cases. Clearly, there appears to have been a learning curve effect as the lead assessor (i.e., the researcher) became more familiar with the application of the overall TBAM methodology.

4.5.2.1 Critique – Evaluation

In general, the arriving at a score for each element would appear to be the most important element of the evaluation phase. However, during the assessment the team learned that more important than the score was the accurate capturing of supporting evidence. This documentation reflected the interrelationships and dynamics that resulted from the probing within each element (i.e., more of the logical connections surfaced). These notes were most important for the assessment team during the construction of the CRT during the Diagnosis phase.

Frequently, arriving at a single score for some of the elements was rather difficult. At times two scores seemed more appropriate than one composite score. For example, in case Alpha the level of participation (MET element 2.2.1) would have received a “high” score of 4 if the question was restricted to engineers, managers, and professionals; but, if the question was focused on shop floor employees the result would have been a “low” sore of 2. Similar situations occurred on one or two elements within the other case studies. These situations were noted in the supporting evidence section of each survey. Perhaps this indicates a gap in the MET based survey methodology or just reflects the unique characteristics associated with each company. One thought is that due to the uniqueness of every SME, there will always be some aspects of a common survey instrument that do not fit as well as other aspects.

While the free format approach in conducting the on-site survey allows a lot of flexibility to accommodate varying manufacturing environments, there are still opportunities to better structure cross functional and hierarchal interactions. This may yield a more consistent overall picture of the manufacturing enterprise.

Generally, the participants that the assessment team interacted with were heavily weighted toward middle and senior level managers. It is thought that a more intentional attempt should be used to include shop floor employees and first line supervisors.

4.5.2.2 Critique – Diagnosis

In the case of Alpha, the CRT was iterated several times between assessment team and the client’s core team. The first iteration of the CRT served as a way to introduce the client to the CRT methodology (e.g., types of entities, logical constructs). It was found that the assessment team did possessed enough understanding to construct a straw man CRT, but not enough intuition to complete the CRT without substantial involvement form the client. Therefore, more time was spent with the client working through issues of the CRT than was initially planned. It is estimated that the client spent two sessions of three hours each with the assessment team iterating through the CRT. These sessions were approximately one week apart. In between these sessions, the assessment team spent 10 hours working on actually constructing the tree.

Since the CRT requires a highly analytical and meticulous thought process, the need for heavy involvement from the client might be a barrier to some of the SMEs to use the TBAM approach. In this case, Alpha's management group was eager to participate with the CRT and very open minded concerning its usefulness. Also on the positive side, heavy client engagement on the CRT, could make for greater buy-in on the recommendations.

The overall construction of the CRT went exceptionally well for Beta and Gamma. The client validated the CRT during the first interaction. This was unlike both Alpa and Beta, - both of the first two case studies required multiple interactions with the SMR before the CRT was validated. The faster response on the CRT may have been, at least partially due to the fact that the assessment team leader had previous interactions with the company and therefore could draw upon more information that perhaps was not explicitly shared during the assessment.

An interesting observation was made during the diagnosis phase. A previously developed CRT for another SME was shown to the Alpha as a way of introducing the CRT to the client through walking through a real application. They immediately recognized the similarities between the example and their own situation. It was jokingly mentioned that this CRT would work for them. In fact, purely coincidentally, Alpha's situation did have much in common with the company that was used as an example. Briefly, the commonalities between the company's included low volume, high mix, and struggles with meeting customer's ship dates. This raises the notion that given a sufficient repository of constructed CRTs, the development of a taxonomy for classifying CRTs may emerge. An assessor could select from among these base case CRTs, subsequently modified the selected CRT for the particular company assessed. This could significantly reduce the time and resources required to perform the diagnosis phase, which is arguably the most difficult, unpredictable, and most difficult to replicate aspect of the TBAM methodology.

4.5.2.3 Critique - Prescription

The method of multi-voting was used gave equal weight to each of the three root causes. However, during the Alpha case it was noted that RT-1 clearly was more dominate than the other two roots (labeled RT-2 and RT-3). This could make the final scoring, which was a strict sum of the multi-votes, not as helpful in terms of guiding the development of the recommendation. In fact, for this case the elements "SMED" and "Concurrent Engineering" did not make to "cut" using the 80% rule, but the assessment team believed they were important enough to be worked into recommendations #1 and #3. This re-enforced the primary use of the PST selection process to serve primarily as a guideline. The PST's primary purpose is to provide the assessment team with a reasonably comprehensive list of "best practices" that should be considered as the recommendations are being developed.

The Alpha case also served to reinforce the need for the recommendations to be specifically relevant within the context of the root causes. The multi-vote should not be a mechanical translation of root causes to prescriptions from the PST. It was very helpful to have the root causes in view during the forming of the recommendations. Also, this underscores the critical importance that the development of the root causes from the CRT is to the overall methodology.

As a result of better understanding the link between the roots from the CRT and the PST selection, the Beta and Gamma cases used a slightly different procedure than Alpha. For these cases, the multi-vote associated with each root cause was specifically referenced so that specific recommendations were track-able to specific root causes. This appeared to work effectively.

Another problem the assessment team encountered was that the team members needed a firm understanding of each of the 91 elements of the PST. This is difficult challenge for even the most experienced members of the team. It was helpful to have a ready reference definition of these elements. However, knowing the definitions is not enough, key members of the assessment team must have sufficient experience in a broad cross section of these elements.

In the case of Alpha and Gamma, the multi-voting was only done by members of the assessment team. It could be argued that the client participation in this exercise could be helpful. However, this has to be weighed against such issues as client unfamiliarity with the PST elements relative to senior members of the assessment team. For case Beta the client's SMR participated in the PST selection activity.

Also, in the case of Beta the PST selection multi-votes were analyzed for each root and a specific recommendation was crafted to target specific roots. This worked extremely well and perhaps helped with the "buy-in" by the client. It was much easier to see the connection between the tree and root causes, and the resulting recommendations. This is the recommended approach to use when the client SMR exhibits a high degree of knowledgeable and understanding of the PST.

Overall the Gamma and Beta cases, the development of the recommendation set went very smoothly and easily. Generally, once the CRT was constructed and validated by the client, the development of specific recommendations was very straight forward. Any rewriting of the recommendations later really served only to improve clarity and was not substantive.

To various degrees in all the case studies, the client had difficulty linking selected PST items to particular recommendations. Because of this, it was determined that prior to the panel review, a slide was developed for each recommendation that references each key issues addressed within the selected PST element. This was added to the documentation of each one of the case studies. This documentation, in terms of PowerPoint slides is contained in Appendix F.

CHAPTER 5

RESEARCH DESIGN & ANALYSIS OF CASE STUDIES

The purpose of this chapter is to present the analysis of the case studies which were pilots of the TBAM approach. This analysis involved the design of a third party review panel that interacted with the documented case studies. The resulting data from each of the case studies reviewed by the panel were analyzed and inferences made concerning reliability and validity associated with the TBAM methodology. Also the panel's critique regarding the overall methodology is discussed.

5.1 Research Design

In research involving human subjects, the problems of validity and reliability are issues of primary importance to the design of the research.[165] Certainly the methodology and the resulting case studies contained within this research require heavy interaction with human participants. Therefore, this work is concerned with both issues of reliability and validity. Generally, reliability deals with the degree of consistency in measurements produced by multiple qualified observers. Reliability is not so much concerned with whether or not the "right thing" is

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[165] Heiman, Gary W., Understanding Research Methods and Statistics: An Integrated Introduction for Psychology, Houghton Mifflin Company, 1998, pp. 62.

being measured, its primary interest lies in the repeatability of the measurements. In contrast, validity is concerned with the extent to which the measurement reflects the intended phenomena of interest. Validity is concerned about whether or not we are measuring the "right thing." [166]

It is impossible to design research so that all concerns regarding reliability and validity are eliminated. "All research suffers to some extent from problems of reliability and validity. The best we can do is minimize the major threats … so that we are as confident in a conclusion as possible." [167] Therefore, it is the responsibility of this research to identify the issues and concerns from both perspectives and to attempt to mitigate their effects on the research findings.

5.1.1 Concerns within Manufacturing Assessments

In order to address these concerns, we must first define clearly validity and reliability must be clearly defined within the domain of manufacturing assessments. For purposes of this research, the following definitions are offered.

- Validity refers to the efficacy of TBAM approach in terms of developing recommendations which result in improving the performance of small to medium size manufacturing enterprises.
- Reliability is concerned with the level of repeatability in terms of the type of prescriptions resulting from the TBAM approach assuming qualified assessors.

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[166] Heiman, Gary W., Understanding Research Methods and Statistics: An Integrated Introduction for Psychology, Houghton Mifflin Company, 1998, pp. 59-60.

[167] Heiman, Gary W., Understanding Research Methods and Statistics: An Integrated Introduction for Psychology, Houghton Mifflin Company, 1998, pp. 63.

For a variety of reasons, these concerns present daunting challenges within this research. No evidence was found in the literature concerning the reliability and validity of any of the previously published assessment approaches (e.g., MBNQA, Shingo, and LESAT). Therefore, this research is plowing new ground with respect to defining and measuring reliability and validity within the context of the manufacturing enterprise assessments.

Specific challenges to achieving validity are next discussed. It would appear as if the best way to measure validity is to compare the performance of the enterprise before and after the implementation of the TBAM derived recommendations. However, the performance of small to medium size manufacturing enterprises is very complex. This longitudinal approach requires sufficient time for the implementations of these recommendations to occur and the impact estimated. This requires a large enough sample size so recommendation impacts are evaluated against the numerous other factors that occur over time (e.g., changes in overall economy, unexpected turnover of key employees, sudden shifts in business volume, changes to customer base, firm's skill in implementation, etc.). In addition, this type of study requires a rather large team of qualified assessors, because the TBAM methodology or something equivalent takes approximately one week to execute for each firm participating in the study. Such a research effort faces the practical challenges of obtaining resources (i.e., assessors trained in the methodology), a substantial number of companies willing to participate, and a relatively long time horizon to conduct the study.

The size and complexity of such a study, just described, to determine validity does not lend itself to rapidly refining early versions of methodologies. Certainly, there is a place for larger more in depth studies, but it is argued that this best occurs after initial development and piloting of earlier versions have shown credibility. This research posits a primary need for developing more responsive means of ascertaining measures of validity without invoking such a complex, and time consuming study.

Similarly, determining the reliability of any manufacturing assessment methodology also faces substantial difficulties. One of the problems is that both the literature and experience clearly indicate that the problem of increased manufacturing performance does not have a unique solution from the perspective that multiple paths can lead to increased performance.[168] Therefore, a variety of prescriptions may be effective in terms of improving enterprise performance at any point in time. It is not only possible, but somewhat likely, that equally qualified assessors could produce different sets of recommendations even using a common methodology. While the use of a common methodology is designed to increase consistency, it is postulated that no assessment methodology can totally overcome the strong biases that exist within highly experienced engineers and managers who tend to constitute the pool of qualified assessors. The biases experienced assessors possess arise out of their own unique set of experiences, training, and previous successes and failures. The critical role of the assessor within any assessment methodology makes it difficult to distinguish between the effect of the methodology and the performance of a qualified assessor. Therefore, the assessment problem is inherently subjective, highly judgmental, and somewhat "noisy" from the perspective of measuring reliability.

Also, field conditions make traditional approaches to measuring reliability impracticable. Typically reliability is measured by independent raters or assessors making independent judgments of the same phenomenon.[169] For this to occur within the manufacturing assessment problem, teams of multiple assessors would need to descend upon a small to medium size manufacturing firm, and conduct parallel assessments using the same methodology. An approach like TBAM requires substantial engagement between the assessment team and key SME

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[168] Kathuria, R. "Competitive Priorities and Managerial Performance: a taxonomy of small manufacturers", Journal of Operations Management, 2000, Vol. 18, pg.638.

169 Heiman, Gary, Understanding Research Methods and Statistics: An Integrated Introduction for Psychology, Houghton Mifflin Company, 1998, pg. 105.

resources. These parallel assessments would need to be done at the same time or very close to the same time due to the rapidly changing nature of SMEs and their business environment. Arguably, this approach would cause significant disruption to the SME. As a result, it was concluded that the typical approach found in the literature in terms of determining inter-rater reliability was concluded as not directly applicable for the manufacturing assessment problem.

5.1.2 Measurements of Validity and Reliability

It is beyond the scope for this research to attack all of the validity and reliability concerns; however, particular concerns are addressed. While noting these concerns, the approach of this research to address these concerns is summarized in Table 5.1.

The ultimate purpose of the assessment methodology is to provide guidelines and structure that enable qualified assessors to develop efficacious recommendations. The academic literature and experience indicates that multiple paths are possible (i.e., a variety of potential recommendations) in terms of improving manufacturing performance.[170] *Therefore, once a basic level of reliability is established, achieving higher levels of validity is more important than increasing reliability in term so f the assessment problem.* The following discussion presents the specific manner in which reliability and validity are measured for the purposes of this research, which was to obtain feedback from the TBAM approach using case studies.

Specifically, reliability (R1) is measured using the level of agreement or consistency between appraisers or panel members. Each panel member was given a fixed number of selections to make from a larger set of PST "best practices." Appraiser consistency is measured as

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[170] Kathuria, R. "Competitive Priorities and Managerial Performance: a taxonomy of small manufacturers", Journal of Operations Management, 2000, Vol. 18, pg.638.

the total number of matches obtained when each member's selections are compared pair-wise with the other members.

Table 5.1

Reliability and Validity Design Concerns

Reliability & Validity Concerns	**Elements of Research Design**
Variation in assessors in terms of background, experiences, and biases.	Qualified Assessors trained in the methodology and tools (i.e., MET survey, CRT, PST). Establishment of a "third party" panel review board to review PST selections and to evaluate recommendations. Elements within the methodology designed to force assessors to pick and rate within taxonomies (i.e., MET and PST). Also the use of the CRT forces the assessors to state assumptions.
Difficulty in isolating the validity of the recommendations from the SME's skill at implementation.	Client was asked to rate in the field the implementability of each recommendation.
Practical concerns about measuring the validity of the recommendations in terms of impact on improving performance.	Client asked to rate the effectiveness and implement-ability of each recommendation. Panel review is asked to rate the effectiveness of each recommendation.
Variation in types of SMEs (i.e., methodology might be valid for one type of SME but not for another).	Three case studies which expose the assessment methodology to diversity in terms of the type of SME and type of industry.
Difficulty in communicating consistently the various issues discovered during the pilot implementations of the TBAM methodology.	Use of a common case study format was used in documenting the case study for presentation to the Panel review board.
Practical concerns about how to bring in multiple perspectives within the field trials of the case study in terms of reliability.	Establishment of a Panel Review Board that serves as an unbiased evaluator of the results obtained in the field and can provide critique of the TBAM methodology
Difficulty in establishing a measure of the reliability of the TBAM methodology by measuring consistency between qualified appraisers. Context does not allow multiple assessment teams to evaluate the same client.	Present the evaluation and diagnosis stages of the case study to the Panel Review Board and ask them to make similar selections as was done in the field from the "best practices" PST. Determine the number of pair-wise matches across all panel review members including the field.
Difficulty in establishing validity without resorting to a long, complex, and resource intensive longitudinal study	Measure the level of agreement between field assessment team and the consensus findings from the panel review board in terms of matches within the "best practices" found within the PST. Feedback from the Panel Review Board and Client's SMR in terms of each recommendation's effectiveness and implement-ability.
Due to the nature of piloting of emerging research, it is possible that key pieces of information are missing in the methodology.	The Panel Review Board was asked to provide critique and review of the entire methodology after all cases were reviewed.

Validity is measured in multiple ways. The first measure of validity termed, V1, is a comparison between the panel's consensus selection from the PST elements and the assessment team's field selection of the PST elements. This measures validity by counting the agreements between the field and the consensus picks of an "unbiased" panel review board. Of course, PST picks are not themselves recommendations, but serve as guides to their development.

The second way in which validity is measured is through obtaining feedback on the field recommendations. This feedback is obtained from the client's SMR, termed, V2, upon completion of the field assessment. The SMR rated each recommendation in terms of effectiveness and implement-ability. The ratings are based on an anchored score, indicating strong agreement (score of 5) or strong disagreement (score of 1) of each recommendation in terms of effectiveness and implementability. Similarly, the panel review members each indicated their feedback on each recommendation in a similar manner, termed, V3. The panel review included a rating of relevance to the core problem, in addition to effectiveness and implement-ability. These measures are summarized in Table 5.2.

Table 5.2

Measures of Validity and Reliability

Concern	**Description**
Reliability	[R1] Number of pair-wise matches across all appraisers on selections from PST elements.
Validity	[V1] Number of matches between Panel as a group and the field PST selections.
	[V2] Average client rating of recommendations in terms of implementability and effectiveness.
	[V3] Average rating of recommendations from individual panel members.

It was particularly insightful to see both the client's and the panel review's evaluation of the recommendation. While both scores provide a measure of validity, it is thought they provide complimentary sources of insight. For example, it is certainly possible for the TBAM approach to produce valid recommendations, but the recommendations not be viewed as such by the client. The panel review exercise provides an additional check, which might indicate that the recommendations are valid, just the client was not able to make the appropriate connection. Clearly one of the challenges of the TBAM methodology is to perform the assessment and to develop the methodology in such a manner as to develop legitimate "buy-in" on the part of the client. Of course, if the recommendations are both well received by the client and rated highly by the panel review board, then perhaps this provides strong indication that the methodology has produced valid recommendations.

An overview of the design of the research results is provided in Figure 5.1. The assessment team performs the assessment in the field using the TBAM methodology. An initial indication of validity (V2) occurs when the client reviews the recommendation. The results of the entire case study are documented in a common case study format. The case studies are presented to a review panel, comprised of senior leaders from the manufacturing community. The review panel provides an objective "third party" review of the cases. The PST selections made by the assessment team in the field are compared to the PST selections of the members of the review panel. The overall pair-wise matches among all appraisers, panel members and the field, provides a measure of reliability (R1). The number of matches for the two appraiser case (i.e., consensus from panel and the field selections) provides a measure of validity (V1). Also the rating of the panel review members regarding each specific recommendation is tracked, which provides another additional measure of validity (V3).

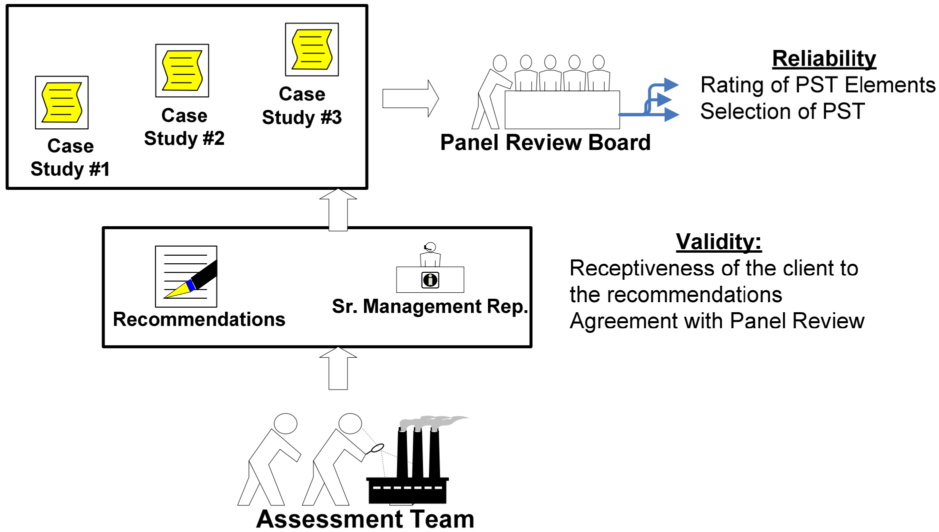

Figure 5.1 Overview of Research Design

5.2 Design of the Panel Review Session

The following section describes the purpose and structure of the panel review session. This session was designed to obtain a more objective review of the field assessment case studies and measures of validity and reliability of the TBAM approach. Also the backgrounds and qualifications of the review panel members are presented.

5.2.1 Purpose and Structure of Panel

The objective of the panel review exercise is to provide an unbiased evaluation of the TBAM derived field recommendations and to critique the overall TBAM approach. The panel was made up of recognized leaders in terms of driving improvements within small to medium size manufacturers.

The review panel meeting was structured to last 6 hours. The session followed the following agenda.

- Informed Consent and Panel Review Background
- Introduction to Research Problem and Approach
- Brief Review of PST Taxonomy
- Case Gamma
    - Presentation of Evaluation and Diagnosis
    - Panel Feedback (individual and group)
- Case Beta
    - Presentation of Evaluation and Diagnosis
    - Panel Feedback (individual and group)
- Feedback on TBAM Methodology

Note that Case Alpha, while initially planned for inclusion in the session, was not evaluated due to insufficient time. Case Alpha was prioritized last because it was the first case study conducted and in many ways case studies Gamma and Beta were easier to follow and evaluate. Therefore, it was more critical to get the full evaluation of the last two cases than to rush the panel review exercise in order to consider all three cases.

The session was initiated by the researcher providing a short overview of the research problem and overall approach. Included in this was an introduction to the TBAM methodology, with particular attention given to the Bolden's taxonomy of best practices (i.e., PST).

The case studies were presented orally and via printed materials; this ensured that each panel member had the same information about each case. The findings and outcomes from the evaluation and diagnosis stages were initially presented to the panel. Very limited questions from the panel were taken, mostly just to ensure clarity. The concern was that extensive questioning on the case might result in speculative answers and that the time allotment might be exceeded.

The panel was then asked to provide individual feedback and then collective feedback regarding the prescription stage. Specifically, each panel review member was asked to multi-vote from the PST across each root cause. Next, each panel member individually selected a fixed number of selections from the PST, commensurate with the number of selections from the field assessment team. Finally, the PST selections were done collectively so that a group consensus emerged.

Each case study member was provided with a packet of information that was used to obtain the case study feedback. This packet included the following items.

- Copies of the PowerPoint presentation of each case which included documentation of the evaluation stage (MET based on-site survey) and the diagnosis (CRT indicating root causes). (Appendix F)
- Copies of a modification of Bolden's taxonomy (i.e., PST) which provided a common set of definitions. [Appendix C]
- Score sheets which provided the case's root causes at the top and a complete list of the PST elements which was used by the panel team to multi-vote and to select their specified number of PST elements. (Appendix D)
- A copy of the CRT was also provided to each member taped to a flip chart pad on an easel located next to each panel review member.

After the initial review of PST element selection was completed, the documentation of the field assessment team's work on the prescription was passed out and discussed. The panel then used a form where each recommendation was scored (Appendix D).

5.2.2 Members of the Review Panel

The research plan, as referenced in the IRB proposal, specified the type of individuals that should comprise the Panel Review Board. Five panel review members were recruited. The qualifications for these members included extensive leadership experience in terms of leading improvements within small to medium size manufacturing companies, a minimum of 10 years of manufacturing experience across a variety of types of industries, expertise in leading improvement paradigms (e.g., lean, six sigma, TOC, TQM), no known association with the case study firms, and a willingness to volunteer time to serve on the research panel.

The following individuals participated in the exercise as members of the review panel: Tommy Jamison, Judy Johnson, John Moore, Michael Harbaugh, and Paul Babin. This research is indebted to each for volunteering their time and interacting with each of the case studies presented. Each member was randomly assigned a code so that their particular responses were confidential. The codes were PRM-1, PRM-2, PRM-3, PRM-4, and PRM-5.

As can be seen from the Figure 5.2, the Panel members not only meet the minimum criteria but are exceptional in a variety of ways. This researcher was very fortunate to have such a distinguished panel. Among the panel members were people who held senior management and executive position experience in a wide variety of industries, including senior staff roles with responsibilities for lean transformations across multiple plants, Vice President/Director of Engineering, Vice President of Operations, General Manager, and Chief Executive Officer of a consulting company. Professional certifications included Six Sigma Black Belts, Professional Engineer, etc.   Overall the panel averaged 27 years of experience in managing, leading, and improving small to medium size manufacturing enterprises.

Panel Member	Academic Background	Experience in Manufacturing	Management Positions	Professional Certifications
PRM-1	BSIE MS in Applied Statistics	35 years	IE Manager, Director of Operations Research, VP of Operations, VP of Manufacturing, VP Product & Process Development	P.E.
PRM-2	BSEE, MSEE, MS in ISE, MBA, PhD in ISE (in-progress)	25 years	Quality Mgr, General Manager R&D, Program Mgr, Director of Engineering	P.E., ASQ – Six Sigma Black Belt, CQE, CRE, CQA, Project Mgm't - PMP
PRM-3	Business, FAA Certification	18 years	General Manager Operations, Senior Manager Operations, Manager Lean Implementation, President – Operations, CEO	Certified FAA Technician, Certified Facilitator, Negotiator, Professional Development Coach
PRM-4	BSIE, MBA	30 years	Manager of IE, Manufacturing Engineering, Materials, Production Manager, Manager of Engineering leadership Development, Senior Manager University Relations	Six Sigma Black Belt, APICS – Certification in Production and Inventory Management,
PRM-5	BSIE, MS in Manufacturing Management	27 years	Operations Manager, Lean Implementation Manager, Project Manager	

Figure 5.2 Overview of Panel Review Members

Also each panel review member was asked to provide information regarding their exposure to major functions within the manufacturing enterprise. They were asked to indicate on a scale of 1 (little) to 5 (extensive) their experience across these key areas. This information is contained in the Figure 5.3. In general the panel's most extensive experience (average ranging from 4.4 to 5.0) was in the areas manufacturing, continuous improvement, and quality. The next level of exposure for the panel was the areas of Engineering, Human Resources, and Information Systems (average approximately 3.6). The lowest level of exposure for the panel was in the areas of Customer Service, Finance, and Sales and Marketing (average ranging from 2.8 to 3.0).

Areas	PRM-1	PRM-2	PRM-3	PRM-4	PRM-5	Overall
Manufacturing	5	5	5	5	5	5.0
Continuous Improvement	5	4	5	4	5	4.6
Quality	5	5	5	3	4	4.4
Engineering & Design	4	5	3	2	4	3.6
Human Resources	4	3	5	4	2	3.6
Information Systems	3	4	4	3	4	3.6
Customer Service	3	3	5	2	2	3.0
Finance	4	3	3	2	2	2.8
Sales & Marketing	3	3	5	2	1	2.8

Each member was asked to rate their exposure to the above functions of a manufacturing enterprise on a scale of 1 (little) to 5 (extensive).

Figure 5.3 Panel Review Members: Exposure to Major Enterprise Functions

In addition, the panel was asked to indicate their exposure to popular continuous improvement paradigms. Each panel member was asked to rate their exposure on a scale of 1 (little) to 5 (extensive). The results from each panel member are summarized in the Figure 5.4. In general, the panel's averaged exposure is close to four across all the major improvement paradigms. Interestingly, two members in particular rated exposure to lean manufacturing as a 5 (extensive), one person each rated exposure to Six Sigma, TQM and TOC as a 5 (extensive).

Areas	PRM-1	PRM-2	PRM-3	PRM-4	PRM-5	Overall
Total Quality Management	4	4	5	4	4	4.2
Six Sigma	5	4	3	4	4	4.0
Lean Manufacturing	3	3	5	3	5	3.8
Theory of Constraints	4	3	5	3	4	3.8

Figure 5.4 Panel Review Members: Exposure to Improvement Paradigms

5.3 Approximate Statistical Test for Evaluation of Appraiser Consistency

This research has developed an approximate statistical test for use in evaluating appraiser consistency. This technique is used to judge statistical significance of the data resulting from the case study panel review in terms of previously defined measures of reliability (R1) and validity (V1). A fuller explanation of this problem and related approximation technique is found in Appendix A.

The basic problem is one of multiple appraisers evaluating an object of interest (in this situation the case study) and selecting prescriptions from a larger set of possible prescriptions. The response variable (X) is the number of selection matches based on all pair-wise comparisons of appraisers. The parameters of the problem are the number of appraisers (A), the number of selections (S) that each appraiser is allowed to select, and the size of the total set of possible prescriptions (N).

The experimental situation just described generally fits the inter-rater reliability problem. After a review of general approaches to the problem of establishing inter-rater reliability, the particular experimental situation just described was not found to be addressed in the literature. Generally the problem is to determine the level of consistency between raters evaluating "n" objects, typically based on an anchored scale or rankings.[171] The situation of interest to this research can be thought of a special case of the general inter-rater reliability problem. Of course, this problem consists of the special case where the set of "n" objects of interest is equal to one and the rating is a selection of prescriptions from a larger set of possible prescriptions. This situation is defined in the Figure 5.5.

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[171] Gary W. Heiman, Understanding Research Methods and Statistics: An Integrated Introduction for Psychology, Houghton Mifflin Company, 1998, pp. 254.

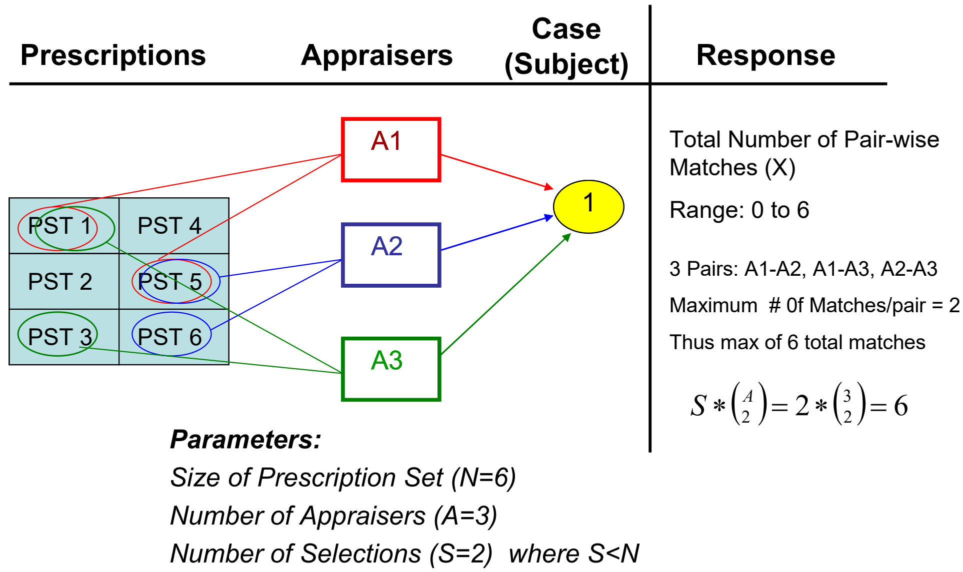

Figure 5.5 Illustration of Inter-Rater Reliability Problem: Appraiser Consistency

A generalized expression for determining the total number of possible pair-wise matches, given the number of appraisers (A) and the number of selections allowed (S) is:

$$Total\_Number\_of\_Matches = S * \binom{A}{2} \quad . \tag{5-1}$$

The challenge is to determine if the response variable (X), which is the total number of pair-wise matches, is consistent with the operation of purely chance causes. If the chance hypothesis can be rejected, then the appraisers are said to hold to at least a minimum level of consistency. In order to determine whether or not the selections are consistent with random chance, the probability distribution of the number of pair-wise matches under the null hypothesis must first be determined. Determining this exactly across all the parameters (i.e., A, S, and N) is somewhat of a challenge. However, the exact probability distribution has been determined for small problems and an approximation method was developed, which appears to work well for these cases.

Specifically, the probability distribution of the number of pair-wise matches is determined exactly for any generalized value of N and for small values of A (i.e., A=2, 3) and S (i.e., S=2, S=3). This work is described in more detail within Appendix A. Clearly, the problem of determining the exact probability distribution of the number of pair-wise matches grows rapidly as the parameters of A and S increase. Because of this problem, a convenient approximation technique was developed. The approximation can be shown in Appendix A to work well for any value of N associated with small values of A and S. The approximation involves using the binomial distribution function. The statistical test is outlined as follows.

H_O: Number of matches is random

H_1: Number of matches is not random

Parameters: number of appraisers (A), number of selected prescriptions allowed each appraiser (S), and the total number of possible prescriptions (N).

Random Variable: the total number of pair-wise matches (X)

It is shown in the appendix that the probability distribution of X (for small values of S and A) is approximated by the binomial function.

$$P(x) = \binom{n}{x} \hat{p}^x (1-\hat{p})^{n-x} \tag{5-2}$$

where

$$\hat{p} \approx \frac{S + \binom{A}{2}}{2N + 1} \quad (5\text{-}3)$$

In Appendix A this approximation using equation 5-3 as the estimate of $\hat{p}$ is evaluated and shown to work reasonably well for small values of S and A. Using the above approximate probability distribution, a p-value can be estimated based on the actual number of pair-wise matches obtained from the panel review of each case study reviewed.

Also, a match index is calculated which allows for comparison between cases. This index is based on scaling the actual number of pair-wise matches (X) by the total number of possible matches which is given by $S * \binom{A}{2}$. This allows the number of pair-wise matches to be compared across cases where the number of appraisers and number of allowed selections may vary. This match index is given by the equation 5-4.

$$Match\_Index = \frac{X}{S * \binom{A}{2}} \quad (5\text{-}4)$$

It should be noted that the match index rate does not define a match probability, but just allows the observed number of pair-wise matches to be scaled.

5.4 Analysis of Cases

The following analysis was made for case Beta and Gamma, which were the only cases evaluated by the review panel. Also, for both cases the number of the same PST is used, which implies N=91.

5.4.1 Case Beta

The data generated by the review of case study Beta resulted in the following analysis, in terms of the reliability measure R1 and the validity measures V1, V2, and V3.

5.4.1.1 Reliability (R1)

Recall, R1 is the number of pair-wise matches obtained across all appraisers making the same number of independent selections from the PST. The PST defines a set of best practices, of which a selected subset provides guidance to the development of recommendations. Therefore, a relatively low number of pair-wise matches indicate a low level of reliability and conversely a high number of matches indicate a high level of reliability.

The Case Beta resulted in the total number of pair-wise matches (X=91) shown in the Figure 5.6 below. These matches are generated from each appraiser making S=14 selections from the N=91 set of PST. This includes using the all of the appraisers (i.e., 5 panel review members and the field assessment) for a total of 6 appraisers (A=6).

	PRM-1	PRM-2	PRM-3	PRM-4	PRM-5	Field
PRM-1						
PRM-2	4					
PRM-3	6	6				
PRM-4	8	3	5			
PRM-5	5	5	9	6		
Field	6	7	8	5	8	
Number of Matches	29	21	22	11	8	

Total Number of Matches	91

Figure 5.6 Case Beta - Unique Pair-wise Matches Based on PST Selection

For the case of Beta (i.e., S=14, A=6) the total number of possible matches is defined as follows.

$$Number\_of\_Possible\_Pair-wise\_Matches = S*\binom{A}{2} = 14*\binom{6}{2} = 210$$

Therefore, case Beta resulted in the following pair-wise match index (i.e., 91 matches out of a maximum number of 210).

$$Match\_Index = \frac{91}{210} = 0.43$$

The approximate p-value associated with the X=91 (total number of pair-wise matches) given the parameters of this case (A=6, S=14, and N=91) is less than 0.0001, which can be observed in Figure 5.7. Therefore, for case Beta the null hypothesis can be rejected and it is concluded that the number of matches is significantly more than would be expected under purely chance causes. Thus there exists an overall level of repeatability between appraisers for this case.

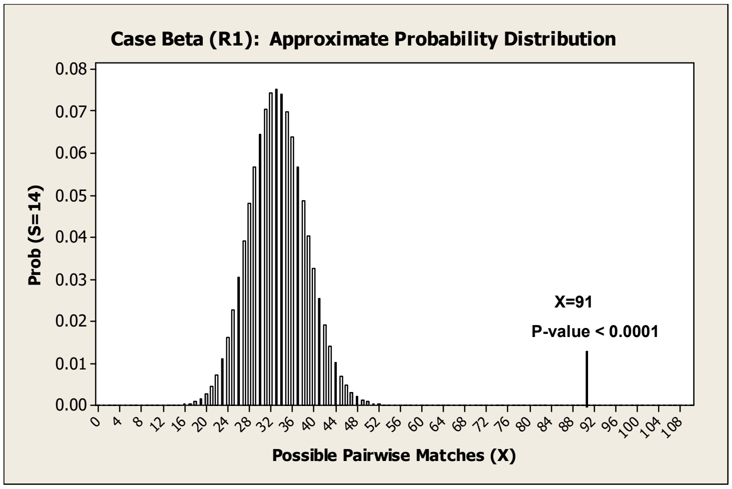

Figure 5.7 Case Beta: Approximate Distribution of Matches (R1) for Case Beta

5.4.1.2 Validity (V1, V2, V3)

The three measures of validity (V1, V2, and V3) are calculated from the data obtained from case study Beta. The consensus PST selections of the panel review board were compared to the field selections of the assessment team. The number of pair-wise matches in this case (i.e., A=2) represents the measure of validity, V1. This serves as a measure of validity because it is hypothesized that the selections of the review panel acting collectively provides an objective and, at least to some degree, an unbiased perspective on the field selections. In the case of Beta, the number of pair-wise matches between the field and the panel was eight, out of a total possible match set of 14. These matches are shown in the Figure 5.8.

PST Element	Panel Selections	Field Selections	Match (Yes/No)
2.A-1 Supply Chain Partnering	X	X	Yes
3.A-1 Quality Improvement Teams		X	No
4.A-1 Total Quality Management	X		No
1.B-1 Reduced WIP		X	No
1.B-2 JIT Production	X	X	Yes
1.B-3 Process Mapping	X	X	Yes
1.B-4 Design for Manufacturability	X		No
1.B-6 Value Engineering	X		No
2.B-3 JIT Inventory Control	X	X	Yes
2.B-5 Logistics Management	X		No
4.B-1 Lean Production	X	X	Yes
4.B-4 Time Based Management	X	X	Yes
4.B-6 Balanced Scorecard	X		No
4.B-7 Link Manufacturing to Strategy		X	No
1.C-4 LT Reduction	X	X	Yes
3.C-3 Cellular Manufacturing	X	X	Yes
1.D-4 CAD and Engineering		X	No
1.D-5 New Process Development	X		No
3.D-4 MRP/ERP		X	No
4.E-4 Culture Change		X	No

Validity (V1)

Number of Matches (X) = 8

A=2

S=14

N=91

Figure 5.8 Case Beta: PST Selection Matches (V1)

In order to properly interpret this score of 8 matches, it is important to determine whether or not the number of matches is consistent with random conditions or not. This was evaluated using the same approximate statistical techniques previously discussed for the reliability measure (R1). The Figure 5.9 below illustrates the approximate statistical test of significance for the validity measure (V1). Since X=8 matches, the null hypothesis of matches due to random picks can be rejected with a p-value < 0.0001. Also, information on the cumulative probabilities used for this statistical test is found in Appendix A.

Case Beta: Approximate Significance Test A=2, **S=14**, N=91

Ho: Number of Matches Due to Random Chance

H1: Number of Matches Not Random

Panel vs Field: 2 Appraisers

Number of pairwise comparisons ("A" items, two at a time)

1

Number of Selections (S)

14

Total Prescription Set (N)

91

Reject H_o → 8

Possible Matches(X)	Cumulative Probability
0	0.3020
1	0.6795
2	0.8986
3	0.9768
4	0.9961
5	0.9995
6	0.9999
7	1.0000
8	1.0000
9	1.0000
10	1.0000
11	1.0000
12	1.0000
13	1.0000
14	1.0000

Using estimate of P for BN
p=(# of pairs+ # of selections) / (2N+1) ***Phat*** ***0.082***
approx. formula

Figure 5.9 Case Beta: Summary of Hypothesis Test (V1)

The other validity measures (i.e., V2 and V3) are summarized in the Figures 5.10 and 5.11 below. The measure (V2) is the client's rating (on a one to five scale) of each recommendation in terms of effectiveness and implementability. The rating was based on a one to five scale, where one (indicates strong disagreement) and five (indicates strong agreement) with the following statements. Overall this measures the client's receptivity to the recommendations.

- The recommendations, if implemented, would have a substantially positive impact on the manufacturing enterprise (effectiveness).

- The recommendation is practical and implement-able without spending excessive time and resources (i.e., implement-ability)

The measure (V3) considers the level of agreement between panel review's evaluation and the field delivered recommendations. A third rating was obtained from the panel in terms of their agreement or disagreement with the following statement.

- The recommendations are targeted at the elimination of root causes (i.e., relevance).

The overall client (V2) rating varied from 3.5 to 4.0 depending upon the recommendation. Generally, the client viewed each of the three recommendations as being effective (i.e., rating of 4). Similarly, the client viewed recommendations #2 and #3 as being implement-able (i.e., score of 4). Recommendation #3, however, received a somewhat lower score of 3.5 from the client in terms of implementability. The client's feedback of recommendation #3 indicated overall agreement with the need to implement the recommendation, but the challenges of how to accomplish the implementation within this particular environment (i.e., high variety, low volume custom engineered job shop) remained unclear.

Interestingly, the average of the panel review members (V3) scored each recommendation slightly higher than the client. However, of primary interest is the fact that the panel's independent evaluation of the recommendations showed that each recommendation was generally relevant, effective, and implementable. This is indicated by each recommendation receiving an average score higher than 4 for each of the three criteria (i.e., relevance, effectiveness, and implement-ability). The result is that the average overall score from the panel ranged from 4.4 (recommendation #1) to 4.8 (recommendation #3).

Case Study Beta **Comparison between Field Recommendations and Individual Panel Review Members**	**Rater**	**Relevance** *"The recommendations are targeted at elimination of the root causes."* *Please rate each recommendation on the folowing scale* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	**Effectiveness** *"The recommendation, if implemented, would have a substantially positive impact on the manufacturing enterprise."* *Please rate each recommendation on the folowing scale* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	**Implement-ability** *"The recommendation is practical and implementable without spending excessive time and resources."* *Please rate each recommendation on the folowing scale* Score 1: Strongly Disagree Score 5: Strongly Agree	**Overall Score**
Recommendation #1 Develop ability to compare requirements with the capacity of key workstations. This will enable the constraint to be identified and appropriate operational measures to be tracked. This should guide improvement actions for increasing system capacity.	Client		4	3	3.5
	PRM-1	5	5	5	5.0
	PRM-2	5	4	4	4.3
	PRM-3	4	5	5	4.7
	PRM-4	4	4	5	4.3
	PRM-5	5	4	5	4.7
Recommendation #2 Develop an overall business plan for establishing the value of rapid lead-time capability. This includes exploring partnerships with suppliers of key raw materials, reorganizing production operations to facilitate flow, finding ways of streamlining pre-production operations, and rationalizing appropriate capital investments. Of particular promise are ways to reduce design complexity (e.g., parametric CAD).	Client		4	4	4.0
	PRM-1	5	4	4	4.3
	PRM-2	5	5	4	4.7
	PRM-3	5	3	3	3.7
	PRM-4	5	5	5	5.0
	PRM-5	5	4	5	4.7
Recommendation #3 Develop a value stream map both "as is" and "to be" for lead-time sensitive products. The "as is" case illustrates the waste involved in the total process. This should include the key activities (i.e., receipt, design, purchase, and fabricate), and the calculation of percent "value add" time for comparison against world class performance. The "to be" case establishes the vision for substantial process improvement. The mapping and transition effort should include a broad cross section of team members.	Client		4	4	4.0
	PRM-1	5	5	4	4.7
	PRM-2	5	5	5	5.0
	PRM-3	5	5	5	5.0
	PRM-4	5	5	4	4.7
	PRM-5	5	4	5	4.7

Figure 5.10 Case Beta: Detail Ratings of Recommendations

Case Study Beta **Comparison between Client Rating and the Rating from the Review Panel (Average)**	**Rater**	**Relevance** *"The recommendations are targeted at elimination of the root causes."* *Please rate each recommendation on the folowing scale* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	**Effectiveness** *"The recommendation, if implemented, would have a substantially positive impact on the manufacturing enterprise."* *Please rate each recommendation on the folowing scale* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	**Implement-ability** *"The recommendation is practical and implementable without spending excessive time and resources."* *Please rate each recommendation on the folowing scale* Score 1: Strongly Disagree Score 5: Strongly Agree	**Overall Score**
Recommendation #1 Develop ability to compare requirements with the capacity of key workstations. This will enable the constraint to be identified and appropriate operational measures to be tracked. This should guide improvement actions for increasing system capacity.	**Client**		4	3	3.5
	Panel	4	4.4	4.8	4.4
Recommendation #2 Develop an overall business plan for establishing the value of rapid lead-time capability. This includes exploring partnerships with suppliers of key raw materials, reorganizing production operations to facilitate flow, finding ways of streamlining pre-production operations, and rationalizing appropriate capital investments. Of particular promise are ways to reduce design complexity (e.g., parametric CAD).	**Client**		4	4	4.0
	Panel	5	4.2	4.2	4.5
Recommendation #3 Develop a value stream map both "as is" and "to be" for lead-time sensitive products. The "as is" case illustrates the waste involved in the total process. This should include the key activities (i.e., receipt, design, purchase, and fabricate), and the calculation of percent "value add" time for comparison against world class performance. The "to be" case establishes the vision for substantial process improvement. The mapping and transition effort should include a broad cross section of team members.	**Client**		4	4	4.0
	Panel	5	4.8	4.6	4.8

Figure 5.11 Case Beta: Detail Average Ratings of Recommendations

5.4.2 Case Gamma

The analysis of data generated by the review of case study Gamma resulted in the following analysis in terms of the reliability measure of R1 and the validity measures of V1, V2, and V3.

5.4.2.1 Reliability (R1)

R1 is the number of pair-wise matches obtained across all appraisers making the same number of independent selections from the PST. The case Gamma resulted in the total number of pair-wise matches (X=100) shown in the Figure 5.12 below. These matches were generated from each appraiser making S=15 selections from the larger set of PST elements (N=91). This includes using the entire set of appraisers 5 panel review members and the field assessment (i.e., a total of A=6 appraisers).

	PRM-1	PRM-2	PRM-3	PRM-4	PRM-5	Field
PRM-1						
PRM-2	4					
PRM-3	5	9				
PRM-4	6	8	7			
PRM-5	5	7	4	7		
Field	5	9	7	9	8	
Number of Matches	25	33	18	16	8	

Total Number of Matches	100

Figure 5.12 Case Gamma: Unique Pair-wise Matches Based on PST Selection

For the case of Gamma (i.e., S=15, A=6) the total number of possible matches is defined as:

$$Number\_of\_Possible\_Pair-wise\_Matches = S * \binom{A}{2} = 15 * \binom{6}{2} = 225$$

Therefore, the case Gamma resulted in the following pair-wise match index (i.e., 100 matches out of a maximum number of 225).

$$Match\_Index = \frac{100}{225} = 0.43$$

The approximate p-value associated with the X=100 (total number of pair-wise matches) given the parameters of this case is defined as less than 0.0001. This can be observed in Figure 5.13. Also, additional information on the cumulative probabilities used for this statistical test can be found in Appendix A. Refer to the appendix for a table that shows the actual the cumulative probabilities. As shown in Figure 5.13, the region for alpha=0.05 is approximately X>50. Therefore, for case Gamma the null hypothesis can be rejected and it is concluded that the number of matches is significantly more than would be expected under purely chance causes. Thus there exists an overall level of repeatability between appraisers.

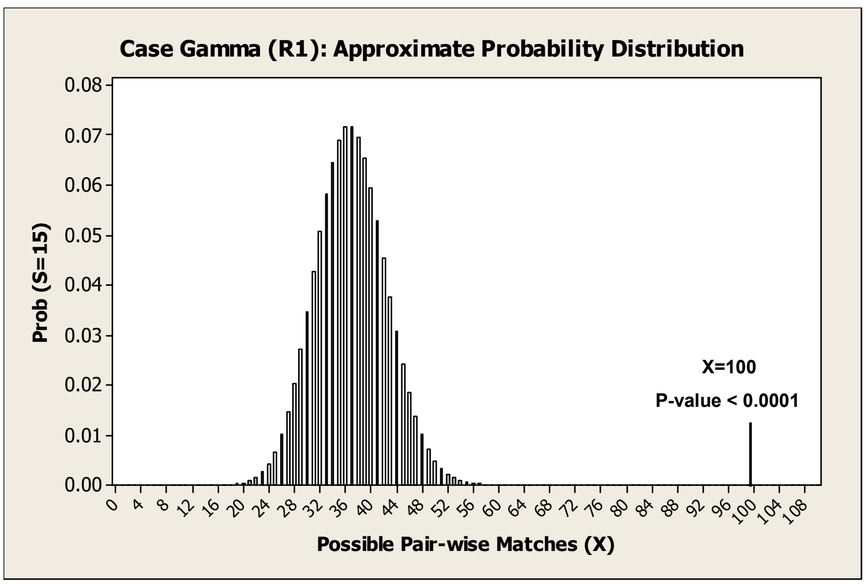

Figure 5.13 Case Gamma: Approximate Distribution of Matches (R1)

5.4.2.2 Validity (V1, V2, V3)

The three measures of validity (V1, V2, and V3) aree calculated from the data obtained from case study Gamma. In the case of Gamma, the number of pair-wise matches between the field and the panel was ten (V1), out of a total possible match set of 14. These matches are shown in the Figure below.

PST Element	Panel Selections	Field Selections	Match (Yes/No)
1.A-2 SPC	X		
1.A-5 Mistake Proofing	X		
3.A-1 Quality Improvement Teams	X	X	Yes
3.A-2 Operator Responsibility		X	
3.A-3 Quality Feedback to Operator		X	
3.A-4 Quality Training	X	X	Yes
4.A-1 Total Quality Management	X		
1.B-3 Process Mapping	X		
4.B-1 Lean Production	X	X	Yes
1.C-4 LT Reduction	X		
3.C-3 Cellular Manufacturing	X	X	Yes
4.D-5 Six Sigma	X	X	Yes
1.E-2 Multi-skilling		X	
1.E-4 Appraisal		X	
1.E-5 Training & Development	X	X	Yes
3.E-2 Team Based Work	X	X	Yes
3.E-3 Job Enrichment		X	
4.E-1 HRM Strategy	X	X	Yes
4.E-4 Culture Change	X	X	Yes
4.E-5 Learning Culture	X	X	Yes

Validity (V1)

Number of Matches (X) = 10

A=2

S=15

N=91

Figure 5.14 Case Gamma: PST Selection Matches (V1)

The Figure 5.15 illustrates the approximate statistical test of significance for the validity measure (V1). Since X=10 matches, the null hypothesis of matches due to random picks can be rejected with a p-value < 0.0001 for the measure V1 for case study Gamma.

Approximate Significance Test A=2, **S=15**, N=91

Ho: Number of Matches Due to Random Chance

H1: Number of Matches Not Random

Panel vs Field: 2 Appraisers

Number of pairwise comparisons ("A" items, two at a time)

1

Number of Selections (S)

15

Total Prescription Set (N)

91

Possible Matches(X)	**Cumulative Probability**
0	0.2535
1	0.6178
2	0.8621
3	0.9636
4	0.9927
5	0.9989
6	0.9999
7	1.0000
8	1.0000
9	1.0000
10	1.0000
11	1.0000
12	1.0000
13	1.0000
14	1.0000
15	1.0000

Reject H_o

Using estimate of P for BN
p=(# of pairs+ # of selections) / (2N+1)

Phat ***0.087***
approx. formula

Figure 5.15 Case Gamma: Summary of Hypothesis Test (V1)

The other validity measures V2 and V3 are summarized in Figures 5.16 and 5.17 below. The overall client (V2) rating varied from 3.5 to 5.0 depending upon the recommendation. The client was particularly receptive to recommendations #2 and #3, since both received the maximum a rating of 5 in terms of both effectiveness and implement-ability. Also, the client generally agreed that recommendation number one was effective (i.e., score of 4), but struggled more with its implement-ability (i.e., score of 3). This may be because recommendation #1 included more references to “jargon” generally known within the lean circles but not always known by a more general business audience (e.g., “5S”, “andon”). In comparison, the average score from the panel review resulted in scores ranging from 3.8 to 4.8 for all three recommendations across all three criteria (effectiveness, implementability, and relevance). The panel appeared to rate recommendation #1 slightly higher than the client in terms of implementation. Perhaps it is because the panel had a greater degree of familiarity with some of the terms in that recommendation. Another interestingly outcome is the client overall viewed recommendation #3 more positively (score of 5) than the panel did (score of 4.1).

Case Study Gamma **Comparison between Field Recommendations and Individual Panel Review Members**	**Rater**	**Relevance** *"The recommendations are targeted at elimination of the root causes."* *Please rate each recommendation on the folowing scale* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	**Effectiveness** *"The recommendation, if implemented, would have a substantially positive impact on the manufacturing enterprise."* *Please rate each recommendation on the folowing scale* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	**Implement-ability** *"The recommendation is practical and implementable without spending excessive time and resources."* *Please rate each recommendation on the folowing scale* Score 1: Strongly Disagree Score 5: Strongly Agree	**Overall Score**
Recommendation #1: Establish a visual management program on the floor so that non-preferred conditions/methods are rapidly detected and corrected and preferred conditions/methods are clearly illustrated. This includes the use of such tools as 5S, one-point lessons, and “andon” indicators at the workstation to indicate current performance status in terms of both quality and throughput [e.g., red – immediate attention, yellow-danger, green-proceed]. Establish regular audit program to ensure compliance and effectiveness. Publicly track audit results so that progress toward a more visual shop floor is tracked more objectively.	Client		4	3	3.5
	PRM-1	5	4	4	4.3
	PRM-2	4	4	5	4.3
	PRM-3	3	4	3	3.3
	PRM-4	5	4	4	4.3
	PRM-5	5	5	5	5.0
Recommendation #2: Accelerate transition away from functional layout toward a cellular layout in order to enhance communications between processes. Continue to apply DOE and other statistical tools to shed light on the effect of processes (e.g., milling) on downstream processes (e.g., polishing). Regularly review capability of the measurement system in terms of repeatability and reproducibility.	Client		5	5	5.0
	PRM-1	5	5	4	4.7
	PRM-2	5	5	4	4.7
	PRM-3	5	5	5	5.0
	PRM-4	5	5	5	5.0
	PRM-5	5	4	3	4.0
Recommendation #3: Develop a technical career path which encourages those that attained a high level of mastery to share, mentor, and develop others. This provides a career growth opportunity outside of management in terms of their mentoring other employees in developing greater skills. Establish “stair step” milestones so that employees can achieve intermediate levels of success. Consider classifying employees in terms of their ability to handle jobs of low-medium-high levels of difficulty and in terms of their skills at performing set-ups and process monitoring. Publicly track development of employees across development benchmarks.	Client		5	5	5.0
	PRM-1	4	4	4	4.0
	PRM-2	4	3	3	3.3
	PRM-3	4	4	5	4.3
	PRM-4	4	3	4	3.7
	PRM-5	5	5	5	5.0

Figure 5.16 Case Gamma: Detail Ratings of Recommendations

Case Study Gamma Comparison between Client Rating and the Rating from the Review Panel (Average)	Rater	Relevance *"The recommendations are targeted at elimination of the root causes."* *Please rate each recommendation on the folowing scale* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	Effectiveness *"The recommendation, if implemented, would have a substantially positive impact on the manufacturing enterprise."* *Please rate each recommendation on the folowing scale* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	Implement-ability *"The recommendation is practical and implementable without spending excessive time and resources."* *Please rate each recommendation on the folowing scale* Score 1: Strongly Disagree Score 5: Strongly Agree	Overall Score
Recommendation #1: Establish a visual management program on the floor so that non-preferred conditions/methods are rapidly detected and corrected and preferred conditions/methods are clearly illustrated. This includes the use of such tools as 5S, one-point lessons, and "andon" indicators at the workstation to indicate current performance status in terms of both quality and throughput [e.g., red – immediate attention, yellow-danger, green-proceed]. Establish regular audit program to ensure compliance and effectiveness. Publicly track audit results so that progress toward a more visual shop floor is tracked more objectively.	Client		4	3	3.5
	Panel	4.4	4.2	4.2	4.3
Recommendation #2: Accelerate transition away from functional layout toward a cellular layout in order to enhance communications between processes. Continue to apply DOE and other statistical tools to shed light on the effect of processes (e.g., milling) on downstream processes (e.g., polishing). Regularly review capability of the measurement system in terms of repeatability and reproducibility.	Client		5	5	5.0
	Panel	5	4.8	4.2	4.7
Recommendation #3: Develop a technical career path which encourages those that attained a high level of mastery to share, mentor, and develop others. This provides a career growth opportunity outside of management in terms of their mentoring other employees in developing greater skills. Establish "stair step" milestones so that employees can achieve intermediate levels of success. Consider classifying employees in terms of their ability to handle jobs of low-medium-high levels of difficulty and in terms of their skills at performing set-ups and process monitoring. Publicly track development of employees across development benchmarks.	Client		5	5	5.0
	Panel	4.2	3.8	4.2	4.1

Figure 5.17 Case Gamma: Average Ratings of Recommendations

5.5 Summary of Cases

The Table 5.3 summarizes each of the measures of reliability and validity for the two cases (Beta and Gamma) that underwent the panel evaluation. These suggested measures of reliability and validity (R1, V1, V2, and V3) were developed, since nothing was found in the literature to deal with this problem. It is suggested that the set of measures presented in this research represent preliminary work on how to measure reliability and validity with respect to the manufacturing assessment problem. However, it is argued that these measures when viewed collectively provide a rapid, responsive, and reasonable approach to the problem.

The primary purpose of these measures was not so much to compare the client's feedback with the panel review's feedback but to obtain independent evaluations the TBAM assessments performed in the field (including both the PST selections and the specific recommendations).

Measures R1 and V1 were both concerned with the level of consistency among appraisers when selecting from the PST. In both cases, using an approximate test of significance, the number of matches was clearly more than the number expected if purely chance causes were in operation. The match index for the R1 measure varied between 0.43 and 0.44 for Beta and Gamma respectively. The match index for V1 varied from 0.57 (in the case of Beta) to 0.67 (in the case of Gamma).

Measures of V2 and V3 deal with review of actual recommendations. The measure of client's receptivity (V2) was strong for both cases in terms of their rating across the criteria of implement-ability and effectiveness (i.e., 3.9 for Gamma and 4.2 for Beta). In addition, the panel review members perception of the recommendations appeared strong as well (i.e., averaged 4.4 for Gamma and 4.5 for Beta). The panel review measures reflected their perception of each of the recommendations in terms of implement-ability, effectiveness, and relevance.

Table 5.3

Summary of Validity and Reliability Measures from Case Studies

Concern	Measure	Beta	Gamma
Reliability	[R1] Number of Pair-wise matches across all appraisers on selections from PST elements.	91* (match index=0.43)	100* (match index=0.44)
Validity	[V1] Number of matches between Panel (Group) and Field on PST elements.	8* (match index =0.57)	10* (match index =0.67)
	[V2] Average Client Rating of recommendations (scale of 1 to 5).	4.2	3.9
	[V3] Average Rating of Recommendations from Individual Panel Members (scale of 1 to 5)	4.5	4.4

* Indicates statistical significance using the approximate test for evaluating appraiser consistency.

In conclusion, the analysis of the two TBAM case studies reviewed by the panel indicates the achievement of at least some level of reliability and validity. Certainly, these results, while encouraging, should be viewed as preliminary. More work needs to be done on a broader range of case studies in order to more clearly determine the reliability and validity of the TBAM assessment approach.

5.6 Review Panel – Feedback on TBAM Methodology

This section focuses on the panel review members critique of the TBAM methodology. This feedback was obtained during the panel review session, but after the two cases were complete by the panel members. As can be seen from the Figure 5.18, the results in terms of the panel's responses were very consistent both between panel members and across the two cases.

Question #1: How effective was the case study documentation in terms of providing sufficient information upon which to perform the review? The average response for question #1 was 4.8 and 5.0 for cases Beta and Gamma respectively. Therefore, it appears as if the documentation provided was sufficient for the panel review members to perform their evaluations.

Question #2: How well did the survey instrument based on the Manufacturing Enterprise Taxonomy (MET) capture needed Information? The average response for question #2 was 4.4 and 4.8 for Beta and Gamma. Therefore, the perception was that the MET based survey did, at least, an adequate job in capturing needed data and information on-site.

Question #3: How effective was the current reality tree (CRT) in terms of depicting the core problem facing the client? The average response for question #3 was 4.2 and 4.6 for the two case studies (Beta and Gamma). Therefore, overall the panel's perception was that the CRT was an effective diagnostic tool.

Question #4: How well did Bolden's modified taxonomy define and organize the set of best practices for the purposes of this research? The average response for question #4 was 4.2 and 4.6 for the two case studies (Beta and Gamma). In general, the Panel thought the PST was useful in defining a set of best practices for use within this research.

Feedback Question	Beta						Gamma						Consolidated Score
	PRM-1	PRM-2	PRM-3	PRM-4	PRM-5	Overall	PRM-1	PRM-2	PRM-3	PRM-4	PRM-5	Overall	
1. How effective was the case study documentation in terms of providing sufficient information upon which to perform the reviews?	4	5	5	5	5	4.8	5	5	5	5	5	5	4.9
2. How well did the survey instrument based on the Manufacturing Enterprise Taxonomy (MET) capture needed information?	4	4	4	5	5	4.4	5	5	4	5	5	4.8	4.6
3. How effective was the current reality tree (CRT) appear to be in terms of depicting the core problems facing the client?	4	4	4	4	5	4.2	4	5	4	5	5	4.6	4.4
4. How well did Bolden's modified taxonomy define and organize the set of best practices for the purposes of this research?	3	4	5	5	5	4.4	4	4	5	5	5	4.6	4.5

Figure 5.18 Panel Review: Feedback on Methodology

All the comments provided by the panel members regarding their perception of the strengths and weaknesses of the TBAM methodology is provided in the Figure 5.19. Some of the comments focusing on the strength of the methodology include the following.

- structured process that can be repeated and improved,
- overall effectiveness of the CRT,
- methodology was comprehensive
- possible use as a self assessment tool,
- forces consideration of weaknesses and best practices.

Many of the comments dealing with the perceived weaknesses of the methodologies include the following.

- Numerous comments focused on heavy reliance on subjectivity and the outcome is a function of the skill of the assessors.
- Lack of a method for directly communicating to senior management
- Need to extend the tool to coordinate implementation. For example, there may be an order, which recommendations should be implemented first, second, and third.

	What are the perceived ***strengths*** of the taxonomy based assessment methodology?	What are the perceived ***weaknesses*** of the taxonomy based assessment methodology?
PRM-1	A good structured process that can be repeated and improved. It is a good tool to involve and educate management.	There is a lack of method to determine how well senior management (i.e., CEO) understands the terminology and tools required to implement change. There is a need to extend the tool to prioritize and coordinate implementation.
PRM-2	I wish I was more skilled in the current reality tree process. It looks really useful for articulating the relationships. Overall it looks quite effective.	The methodology requires a very knowledgeable assessor. The PST had so many elements to choose form and some were overlapping.
PRM-3	The instrument is comprehensive in terms of its scope which provides for cross correlation of individual data points.	Contains a substantial (perhaps too strong a word) amount of subjective analysis, particularly in the tree analysis relative to answering the why questions.
PRM-4	Structured and organized approach to improvement. Good visual management, communication tool. It appears to be easy to understand and repeatable. It could be used as a self-assessment tool.	Development of the CRT is good in that it causes the user to think through the processes and implications. However, it can be somewhat subjective, depending on the background and experience of the participants. The definition of the terms, and the terms themselves can overlap, so to get discrete answers can be a challenge.
PRM-5	It forces consideration of all best practices and exposes weaknesses that are likely not considered by the manufacturer.	The assessment tools are subject to subjective influences of the evaluators. I think it would require several assessors to cancel the subjective elements.

Figure 5.19 Panel Review: TBAM Strengths and Weaknesses

CHAPTER 6

CONCLUSIONS

This chapter provides a brief summary of the need, the research problem, and corresponding research objective. In addition, the contributions of this effort to the overall body of research dealing with manufacturing performance are presented. Finally, proposed future research topics are identified and briefly discussed.

6.1 Summary of Research Need, Problem, and Objective

At the beginning of this dissertation, the motivation and objective of this research was clearly identified. The research need is perhaps best illustrated by U.S. Commerce 2003 report which stated that small and medium size manufactures have had long standing difficulty in obtaining high quality, unbiased advice; and are, in general, unfamiliar with best management practices.[172] Interestingly, most of the current activity regarding manufacturing assessments occurs by consultants trying to sell predefined solutions. Also the current academic literature reflects a plethora of survey-based research efforts which attempt to relate various factors to enterprise performance. However, little emphasis was found regarding how to best address plant-specific problems via the development of an assessment methodology. Therefore, the following problem statement was put forth.

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172 Panel Report of National Academy of Public Administration for the US Department of Commerce, NIST's Manufacturing Extension Partnership Program, Report 1: Re-examining the Core Premise of the MEP Program, September 2003, pg. 16

> There is not a consensus among practitioners concerning how to perform an objective assessment of small to medium size manufacturing enterprises. No published work has been found which either develops the theoretical framework or provides an overall methodology for addressing the assessment problem. This proposed research attempts to develop a theoretical framework enabling practitioners to bridge the gap between research findings and the needs of manufacturers.

In addressing this problem the following objective was established.

> The objective of this research is to develop an assessment tool that rapidly and accurately diagnoses core problems facing the enterprise and develops a set of powerful recommendations; which, if implemented, results in improved performance. This tool is targeted to be accomplished through the development of an assessment methodology, that draw upon taxonomies of manufacturing enterprises and best practices, in such a manner as effective recommendations are produced.

Numerous challenges were encountered and overcome in order to achieve this research objective. The major challenges are enumerated below.

- No classification scheme was found in the literature to characterize manufacturing enterprises in a manner suitable to serve as the basis for supporting an overall assessment methodology.
- While publications were found that support the linkage between some best practices and enterprise performance, it was not clear whether or not these best practice classification schemes were suitable for use within an overall assessment methodology.
- No assessment methodology was found in the literature that results in specific recommendations. The only assessment instruments found were oriented toward a

predefined solution, e.g., Toyota Production System (TPS). Also published assessment methodologies – e.g., Baldridge Award (MBNQA), and Shingo Award – were found to be evaluation driven, in terms of seeking to determine whether or not specific criteria are met. Clearly these approaches were not designed to deliver recommendations.

- No approach was found in the literature to define and quantify reliability and validity concerns within the domain of manufacturing assessment methodologies.

6.2 Research Contributions

The major contributions of this research to the body of knowledge concerning manufacturing performance and assessments of manufacturers are discussed in this section. This research provides the following key deliverables.

- Development of a Manufacturing Enterprise Taxonomy (MET)
- Modification of an existing taxonomy to serve as a Production System Taxonomy (PST)
- Development of a first generation Taxonomy Based Assessment Methodology (TBAM)
- Development of a Case Study-Review Panel approach for dealing with reliability and validity concerns.

These results are summarized in Table 6.1 and further discussed in the following narrative.

Table 6.1

Contribution of this Research

Problem	Deliverable	Benefit
None of the classification schemes found in the literature to characterize manufacturers were sufficient to support an overall assessment methodology.	Manufacturing Enterprise Taxonomy (MET) synthesizes published research concerning important factors that influence performance and other published assessments (i.e., MBNQA, Shingo Prize, and LESAT). The use of MET within the overall assessment methodology was defined and tested.	The MET is the basis for an on-site survey instrument. It focuses inquiry within a rapid one to two day on-site time frame. Based on case study and review panel feedback, evidence indicates that the MET based survey is effective in terms of evaluating current condition of the SME.
Literature review resulted in some evidence linking particular practices with enhanced performance. However, there are relatively few attempts at developing a classification scheme. It is unclear whether or not the published taxonomies were suitable for use within an overall assessment methodology.	The Production System Taxonomy (PST) is a modest modification of Bolden's taxonomy. The use of this taxonomy within the overall assessment methodology was defined and tested.	Facilitates efficient development of recommendations based on identification of root causes to performance barriers. Based on case study and review panel feedback, evidence indicates that the PST is an effective guide in formulating recommendations.
No suitable assessment methodology was found in the literature to address the problem of providing unbiased advice to SMEs. There are some attempts at defining objective criteria for assessments (e.g., MBNQA) but all are evaluation focused as opposed to recommendation focused. Limited presence in the academic literature with narrow scopes (i.e., self-assessments, quality assessments). Current practice is primarily dominated by consultants promoting predefined solutions.	A first generation Taxonomy Based Assessment Methodology (TBAM) explicitly targets rapid diagnosis of core problems and provides targeted recommendations for use with SMEs.	TBAM partially addresses the National Research Council's identification of the lack of "unbiased advice" as a barrier for increasing SME performance. Results from the pilot application in three different SMEs revealed encouraging results in terms of the client's receptivity and results from the third party review panel.
No approach was found in the literature to define and quantify reliability and validity concerns within the domain of manufacturing assessment methodologies.	Reliability and validity are defined for this research problem and a set of preliminary measures were developed. These measures were derived for a case study-panel review session. An approximate statistical test for evaluating these measures was developed.	Based on the preliminary measures for validity and reliability, the TBAM approach shows promising results. In general, the review panel indicated agreement with the specific recommendations contained in the case studies and in the overall TBAM methodology.

Development of MET: A manufacturing enterprise taxonomy (MET) has been developed. This MET is derived from a synthesis of published findings regarding factors that influence manufacturing performance, as well as, other published assessment methodologies (i.e., MBNQA, Shingo Prize, LESAT). The specific objective of the MET is to classify a specific manufacturing firm based on a relatively few attributes that the literature suggests are the most critical. This taxonomy, in turn, is the basis for a rapid (i.e., one to two day) on-site survey instrument designed for use with SMEs. A mechanism (i.e., anchored scoring) was developed which enables an assessor to classify the firm within an overall taxonomy consisting of 55 elements across 10 major attributes (taxons). The survey was further enhanced based upon feedback from the three case studies. General results based on the pilot case studies, feedback from clients, and the review panel indicates the MET based survey instrument performed well within the assessment context.

Production System Taxonomy (PST): A review of the literature on classification schemes of best practices suggested that Bolden's taxonomy of best practices was, with some modification, suitable for use within the assessment methodology. This modified taxonomy served as the Production Systems Taxonomy (PST) within an overall assessment methodology. In general, the objective of the PST is to structure the solution space so assessors are aided during the prescription stage. Specifically, the PST provides a checklist from which a subset of practices is selected by the assessors, based upon relevancy to the previously identified root causes. These selected PST elements provide overall guidance to the development of specific recommendations, which is the objective of each assessment. Results from the analysis of the case studies indicate that the version of the PST presented within this research was generally effective in terms of its use within the assessment process.

Development of TBAM: A taxonomy based assessment methodology (TBAM) was designed and developed as the major research outcome associated with this effort. The overall assessment framework includes three basic stages: evaluation, diagnosis, and prescription. The ultimate outcome of the TBAM approach is to produce a set of recommendations which target improvement of SME performance. The ultimate goal of the TBAM approach is to enable the assessors to complete the assessment within a focused time period (e.g., within one week). The TBAM approach draws upon the previously discussed taxonomies (MET and the PST) as key components. The reason for the emphasis on taxonomies is that they are helpful in terms of more clearly defining the assessment domain. It is argued that this use of taxonomies enables a more defined and less subjective approach for performing the assessment. The MET parsimoniously attempts to describe the SME in terms of important attributes. The PST structures the solution space of best practices. The Current Reality Tree serves as the linkage between the evaluation of the firm (i.e., MET) and the selection of prescription (i.e., PST) so that effective recommendations are formulated. The structured TBAM approach as defined within this research enables the integration of future enhanced versions of the taxonomies. The results obtained from the case studies and the feedback from the panel review was very encouraging. The TBAM approach performed well in terms of preliminary measures which provide an indication of reliability and validity.

Case Studies: The TBAM approach was piloted using three case studies. Each of these cases involved the "live" application of the methodology within three different small and medium size manufacturers. As a result of pilot activities, feedback was obtained and certain aspects of the methodology were clarified and enhanced. Some of the most important observations are summarized below.

- *Most important finding regarding the evaluation stage* – Prior to the case studies, the fit within the MET was thought to be of the most interest. However, it became apparently very quickly during the piloting activity that the most important information was the notes (i.e., evidences) which were used to support the anchored scoring. These notes generally captured the underlying relationships and dynamics within the client that were most critical in terms of the diagnosis stage. To some degree, everything accomplished during the evaluation stage was focused on developing the assessment team's intuition about the client, which enabled the initiation of the diagnosis stage.
- *Critical nature of the Current Reality Tree* - Clearly the most important link in the TBAM is the diagnosis stage, and in particular the current reality tree (CRT). In retrospect, the most important activities within evaluation concerned preparing the assessment team to develop an effective initial CRT. Certainly, the most difficult, time consuming, and most unpredictable aspect of TBAM is the construction and validation of the CRT. However, in the opinion of this researcher, supported by comments from the review panel, the CRT was the most powerful aspect of TBAM. Once the CRT was validated with the client's senior management representative the subsequent steps were straight-forward, including the most critical – formulation of recommendations.
- *Selected PST elements are more of a guide than a general solution* – Prior to the case studies, it was thought that the primary use of the PST selection was to specify, in general, the type of recommendation produced by TBAM. However, in actual practice the role of the selected PST elements is one of primarily a guide in the development of recommendations. It is hypothesized that this results from several

reasons, including the relatively large number of PST elements, overlapping definitions within the PST, and the over-riding need to contextualize the recommendations based on specific targeting of the root causes from the CRT. It appears to this researcher as if the root causes from the CRT really drive the recommendations. The PST selection is an aid in the development of recommendations, primarily as a checklist which helped ensure that relevant best practices are not overlooked. Upon review of each recommendation, generally most if not all the selected PST elements are clearly referenced within the recommendation statements.

- *Concern regarding general applicability of TBAM* – The level of interaction required by the client in the construction and ultimate validation of the CRT may restrict its application. Since the CRT is a rather tedious and difficult tool, some clients may not have the tolerance for engaging with the assessment team in a manner required to develop an effective CRT. For the Alpha case, in particular, to a lesser extent Beta the validation of the CRT took several iterations. However, it should be pointed out that case Gamma the CRT validation was achieved with only one iteration. This may indicate a learning effect by the assessment team, so this concern may not be as big as initially thought, as the assessment team gains proficiency in the methodology.
- *Possible Role of Narrative* - Based on the conduct of case study Beta, it was observed that the writing of the narrative describing the results from the evaluation stage (i.e., MET based on-site survey) appeared to aide considerably in the construction of the CRT. Since the assessment team is almost always generally unfamiliar with the client prior to the assessment, it is speculated that the act of writing forced the researcher to think more deeply about the underlying relationships. Perhaps this indicates that a

manufacturing enterprise is more like a novel than a mathematical equation. Interestingly, one of the publications noted the important use of a technique called "memoing." "Memoing" was defined as "the generation of narrative, tabular, and graphical documents meant to extract meaning from low level data based and create higher-level theoretical categories, concepts and relationships."[173] This warrants further investigation into its possible role in terms of further developing the assessment methodology.

- *Panel Review Process:* The case study-panel review process was designed and implemented, because of the need to obtain an unbiased third party review of TBAM. The review was conducted through the TBAM operation as represented in the case study and overall. This involved presenting the TBAM based case studies to a "blue ribbon" panel of experts. This panel consisted of leading senior managers with substantial experience leading improvements within small to medium size manufacturing enterprises. The primary purpose of the panel-review process was to obtain an external perspective in terms reliability and validity.

- *Measures of Reliability and Validity:* This research has advanced the notions of validity and reliability within the domain of manufacturing assessment methodologies. This involved obtaining feedback through the case study-panel review process. The case studies were formally presented to a review panel, where measurements of validity and reliability were obtained. A set of responsive measures for reliability and validity was defined within the context of this research (R1, V1,

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[173] Matthew Ford, James Evans, Charles Matthews, "Linking self assessment to the external environment: an exploratory study", International Journal of Operations and Production Management, Vol. 24, No. 11, 2004, pp. 1175.

V2, and V3). However, in order to properly interpret some of the data arising from the panel review process, an approximate statistical test for evaluating appraiser consistency was developed.

- *Conclusions regarding TBAM Based on Analysis from Case Studies* - Using the case study based-panel review process, the TBAM methodology achieved some level of validity and reliability. However, it is argued that validity is more important than reliability for the manufacturing assessment problem. This is because there are many paths available to drive improvements.
    - In terms of the measures R1 (PST matches between all appraisers) and V1 (PST matches between the consensus of the panel and the field assessment team), the conclusion was to reject the null hypothesis that the number of matches was merely due to random chance. This required the use of an approximate statistical test for evaluating appraiser consistency. These results, while promising, should be viewed as preliminary and further tests conducted across a wider set of case studies.
    - Feedback obtained from the review panel in terms of their perception of the overall methodology was positive. This included positive feedback about the role of both taxonomies (i.e., MET and PST). The indications were that the panel perceived the TBAM approach and its associated recommendations were generally relevant to the core problems, effective in terms of improving performance, and implementable.
    - Specific comments from panel members revealed that the TBAM approach was in their opinion "a structured process that can be repeated", "comprehensive and effective", and "forced consideration of weaknesses and

best practices." However, other comments noted that the still included "a high level of subjectivity", "results were dependent upon the skills of the assessor", and "order of recommendation implementation not considered." Certainly these comments indicate there remains much room for improvement.

6.3 Proposed Extensions to Research

When consideration is given to additional research topics which emerge as a result of this work, a couple of major directions come to mind. First, there are many opportunities to improve TBAM approach including improving aspects of the methodology, integrating either enhanced or improved taxonomies, and continuing to develop measures of validity and reliability. The ultimate goal of this direction is continual enhancement with respect to the originally intended purpose – support for the formulation of specific recommendations for specific SMEs. In addition, a second focus also emerges, which is to use the TBAM or a related instrument, as the basis for a new way of performing case study research within operations management. These avenues of future work are further discussed below.

6.3.1 Enhancements of TBAM Assessment Approach.

Numerous improvements should be investigated in order to improve the current version of TBAM. Opportunities exist to tighten up some steps within the methodology, reduce the level of subjectivity, and streamline the execution.

Clearly, one of the major opportunities remains in reducing the subjective influences on the TBAM approach, to the degree possible. This was identified by the review panel when asked about weaknesses of the current version of TBAM. Of course, it is perhaps impossible to completely eliminate subjectiveness. This domain is inherently subjective and will always, to some extent, depend upon the skill of the assessor. However, the better defined the logical connections are, the more transparent the assessment becomes and the more "reviewable" by others (i.e., panel review) relative to reliability and validity concerns.

Some of the ideas which should be further pursued include the following.

- Investigate the greater use of quantitative measures (e.g., response ratio, absolute benchmarking) within the overall methodology.
- Explore mechanisms, other than a simple multi-vote, for performing the PST selection step.
- Address, in many instances, the order in which the recommendations should be implemented.
- Enhance the MET and the PST taxonomies.
- Explore whether or not a taxonomy of CRT's can be established. It would be helpful if the assessment team selected a generic tree based upon the conditions uncovered during the evaluation stage. There is some indication that generic CRT's could be developed and would be useful. This could potentially reduce the time, resources, and client involvement in obtaining a validated CRT. Perhaps a relationship can be established between where the SME fits within the MET and the which generic CRT is most relevant.
- Explore the use of other aspects of Goldratt's Thinking Process, beyond the CRT, such as the Future Reality Tree, Evaporating Cloud, and Pre-Requisite Tree. Of course, the goal remains to be able to complete the full assessment within a one week period.

- Develop a method for measuring the relationship of a particular root cause to the impacted UDEs. This would enable the assessors to understand which of the root's has the largest impact.
- Develop a stronger connection to the critical role that Porter's competitive strategy plays in the way the firm is assessed. Additional comments on this topic are found in the appendix.
- Consider the use of a more intentional approach during the evaluation stage for obtaining feedback, both horizontally across the organization's functions, and vertically from shop floor to management. This should include cross functional, hierarchical, and shop floor employee perspectives. In the case studies the primary interactions were with senior management, middle management, and senior staff.
- Explore the use of other survey approaches which could be used prior to the on-site visit in order to give the assessment team a better understanding of the issues they are likely to be faced with during the on-site phase of the assessment.
- Investigate whether elements of the modified Bolden's taxonomy can be better classified. Perhaps the practices should be clustered in order to reduce the number of elements within the PST.
- Investigate alternative ways of structuring the PST that deal in a more explicitly manner, the clustering of practices around their fit within major production system approaches (e.g., Toyota Production System, Factory Physics, and Theory of Constraints). It is proposed that two major elements comprise this taxonomy: "commonalities" and "distinctives." "Commonalities" represent the set of commonly accepted performance enhancers. These will be determined largely from the literature, but also possibly drawn

from experience and expert judgment. These attributes have reached broad acceptance regardless of the production system bias. For example, efforts to reduce waste and non-value added activities, reduction in process variability, reduced setup time, particular quality practices, use of cross functional teams in solving problems, and bottleneck management. On the other hand, “distinctives” refer to those practices which are peculiar to a particular aspect of one of the major production system theories. Some of these are substantive differences like comparing the production control methods of drum-buffer-rope and kanban. They are two fundamentally different two approaches to the production control problem. Other elements reflect differences in perceived value: for example, the Toyota Production System places extremely high values on standardization, while TOC does not take a contrary position, but places very little emphasis on standardization. In this case, the “distinction lies in a difference in relative importance between approaches.

6.3.2 Additional Enhancements: Measures of Validity and Reliability

Determine additional ways of measuring validity and reliability, without resorting to long and time consuming longitudinal studies. This should include additional work on the approximate statistical test for appraiser consistency. Some concepts that warrant further pursuit include the following.

- Monte Carlo method to better evaluate the use of the approximation method based on the binomial.
- Can a better closed form estimates of the binomial parameter “p” be developed for use within the binomial approximation method?

- How robust is the statistical technique developed within this research? Also what other kinds of problems might exist and represent good potential application areas.
- Can we go beyond the foundational hypothesis regarding whether or not the number of matches are consistent with random chance and develop the equivalent of two sample and ANOVA type of tests?

6.3.3 Argument for a New Paradigm within Operations Management

Clearly, there has been a gap between operations management research and enhanced practice. For example, the greatest advances have not come from the research community but from people in the field, typically either having responsibility for or consulting with actual operations (e.g., Deming, Ohno, Goldratt, Toyota, and Motorola). This argues for the research to more fully engage with actually how operations are improved, rather than just relying upon survey data collected across a large sample of firms.

This research advocates that a new paradigm needs to emerge regarding operations management research. Most of the research in this field deals with collecting data via survey instruments so that specific hypothesis about the relationship between factors and performance are tested. According to some publications within the field, this approach has proven difficult to consolidate new knowledge and move forward an overall research agenda. "… we can distinguish between two basic types of studies. First OS (operations strategy) scholars have conducted in-depth case studies of individual companies operating in specific business environments. Through these case studies, we gain deep insight into individual business situations; however, the limitation is that it is impossible to distinguish between idiosyncratic and more generalizable aspects of the phenomena. Second, OS researchers have conducted large-sample studies using surveys aiming at admittedly more superficial, but at the same time more (statistically) generalizable, results."[174]

Similarly, Davies and Kochhar (2002) provide the following critique of the practice-performance literature. "There has been limited work in the area of explicitly linking practices to performances in the area of manufacturing. Although there is a large element of quantitative data available of performance and performance trends, there tends to be a high use of perceptual and descriptive data on the reasons behind the trends, leading to a high level of subjectivity. Due to this level of subjectivity, studies have had varying results which can be explained by the successes or failures of their own methodologies. Future research should look to learn from the criticism of previous studies and eliminate the subjectivity of the findings, whilst attempting to offer more empirical evidence on the relationship between practice and performance." [175]

The current research approaches in the literature, while certainly helpful in many respects, may miss the most fundamental relationships that are more deeply embedded within the manufacturing firm. Therefore, this research argues for a more active approach to field research. In order to progress using this approach, more work is needed in terms of further defining case study research protocols for use within research on manufacturing enterprises. Clearly, there is a need for a case-based instrument that enables a deeper exploration into the dynamics of a manufacturing enterprise, yet still captures findings in a manner that facilitates statistical generalizations based upon a sample of manufacturing firms. While this research has been primarily interested in the development of recommendation-driven assessment methodologies, it

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174 Mikko Ketokivi, Roger Schroeder, "Manufacturing practices, strategic fit and performance: A routine-based view", International Journal of Operations & Production Management, Vol. 24, No.2@, 2004, pp. 171.

175 Davies, A.J. Kochhar, A.K., "Manufacturing Best Practice and Performance Studies: A Critique", International Journal of Operations and Production Management, Vol. 22, no. 3, 2002, pp. 302.

appears as if the TBAM approach or something similar could be used to test particular situation-practice-performance-relationships. This would enable the current state of research to move from observing merely correlations within large and complex datasets, toward documenting cause and effect relationships present within the firm. It is on this basis that generalizations can be made across companies.

In order to move forward this research agenda, consideration should be given to the given to following challenges.

- A pre-requisite is to have an instrument/methodology that has achieved some level of reliability and validity. The effectiveness of TBAM, based on the results of this research appears promising.
- Is there a relationship across firms in terms of linking the SMEs fit within the MET and its selected items from the PST? This would test the validity of the premise of whether or not similar types of SMEs tend to have similar types of problems which connect to similar types of prescriptions.
- Explore further the complementary nature between survey-based research and assessment-based research.
- Use of TBAM to particular hypothesis regarding manufacturing enterprise performance.

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APPENDIX A

APPROXIMATE STATISTICAL TEST: APPRAISER CONSISTENCY

Appendix A - Approximate Statistical Test for Evaluating Appraiser Consistency

The problem addressed by this technical note is how to develop a statistical test for determining whether or not the number of pair-wise matches is consistent with what one would expect under purely chance conditions. Specifically, within the context of this research, the problem deals with determining the statistical significance for measures of reliability and validity (i.e., R1 and V1 respectively).

A1. Introduction to the Problem

The basic problem is one of multiple appraisers evaluating an object of interest (in this situation a case study) and selecting prescriptions from a larger set of possible prescriptions. The response variable (X) is the number of selection matches based on all pair-wise comparisons of appraisers. The parameters of the problem are the number of appraisers (A), the number of allowed selections (S), and the size of the total set of possible prescriptions (N). As discussed in chapter five, this experimental situation generally fits the inter-rater reliability problem. Typically, the inter-rater reliability problem is to determine the level of consistency between raters evaluating "n" subjects, typically based on an anchored scale or rankings.[176] This is accomplished through different types of correlation analysis, with the objective of establishing a correlation coefficient describing the level of agreement between raters. However, the situation of interest, is a special case of the inter-rater reliability problem, where the set of objects of interest is equal to one (i.e., n=1) and "ratings" are the results of multiple appraisers making a fixed selection from the PST. This experimental situation of interest is defined in the Figure A1 below.

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[176] Understanding Research Methods and Statistics: An Integrated Introduction for Psychology, Gary W. Heiman, Houghton Mifflin Company, 1998, pp. 254.

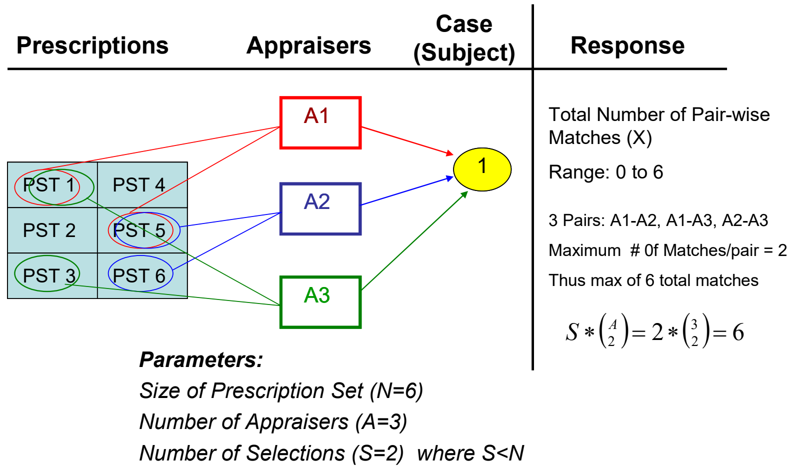


Figure A.1. Illustration of the Appraiser Consistency Problem

A generalized expression is available for determining the total number of possible pair-wise matches, given the number of appraisers (A) and the number of selections allowed (S).

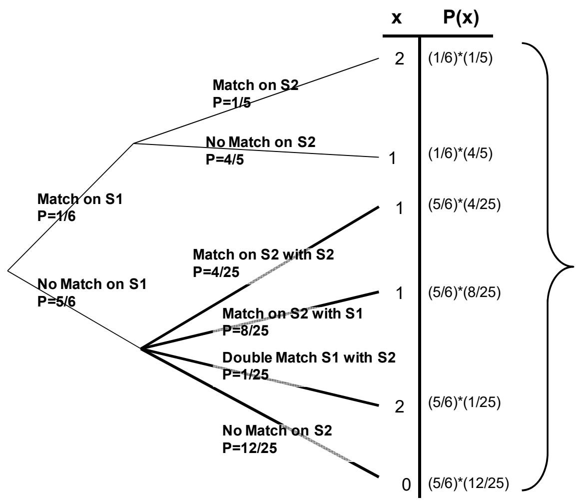
$$Total\_Number\_of\_Matches = S * \binom{A}{2} \tag{A-1}$$

The challenge is to determine if the response variable (X), which is the observed number of matches across all pair-wise comparison, is consistent with the null hypothesis condition of the operation of purely chance causes. If the chance hypothesis can be rejected, then the appraisers are said to hold to at least a minimum level of consistency. In order to determine whether or not the selections are consistent with random chance, the probability distribution of the number of pair-wise matches under the null hypothesis must first be determined. Determining this probability distribution across any values of the parameters of A, S, and N is not a straight-forward task. The difficulty stems from finding a closed form exact solution to the problem. This situation was found to not fit any of the typical discrete probability distributions (e.g., binomial and hyper-geometric). Another challenge is that the size of the problem grows rapidly as the values of the parameters, A, S, and N increase. However, an approximation approach based on the binomial distribution was developed by this research, which was shown to work well for the certain cases (i.e., small values of A and S). It is assumed that this approximation technique works reasonably well for larger values of A and S, but the verification of this left for future research.

In order to address this challenge, the problem will first be worked so that an exact solution is determined for small values of S and A (i.e., A=3, S=2; and A=3, S=3). Next the binomial approximation approach is developed and compared to the exact solutions obtained. Finally, the adequacy of the approximation approach is evaluated and comments are provided in terms of future work in this area.

A2. Development of Exact Probability Distribution for Small A and S

In order to develop the exact probability distribution for small values of A and S, it is helpful to begin with a small value of N as well. Later, it will be shown that the results can be generalized for N. Let's first consider the case where N=6. The following decision tree, Figure A2, shows all the match outcomes for any pair-wise comparison between appraisers for the N=6 and S=2 case.



# of Matches (x)	P(x)
0	P_0=0.400
1	P_1=0.533
2	P_2=0.067

Figure A.2. Match Probability for Any Appraiser Pair (N=6, S=2)

The next step is to extend this to the A=3, which means that there are 3 appraiser comparisons (i.e., appraiser #1 to #2, appraiser #1 to #3, appraiser #2 to #3). For each pair-wise comparison the total number of match varies from zero to two. Therefore, a total of six matches are the maximum number of matches possible. The range of possible matches which can result from this experiment are from 0 to 6, where the maximum number of matches is determined as follows (using equation A-1).

$$S\binom{3}{2} = 2(3) = 6$$

Therefore the calculation of the exact probability distribution for A=3, S=2, and N=6 is as follows.

$$P(X=0)=P_0^3=(0.40)^3=0.064$$
$$P(X=1)=\binom{3}{2}P_1P_0^2=3(0.533)(0.40)^2=0.2560$$
$$P(X=2)=\binom{3}{2}P_1^2P_0+\binom{3}{2}P_2P_0^2=3(0.533)^2(0.40)+3(0.067)(0.40)^2=0.3733$$
$$P(X=3)=P_1^3+\binom{3}{1}P_1P_2P_0=(0.533)^3+6(0.533)(0.067)(0.40)=0.2370$$
$$P(X=4)=\binom{3}{2}P_2^2P_0+\binom{3}{2}P_1^2P_2=3(0.067)^2(0.40)+3(0.533)^2(0.067)=0.0662$$
$$P(X=5)=\binom{3}{2}P_2^2P_1=3(0.067)^2(0.533)=0.0071$$
$$P(X=6)=P_2^3=(0.067)^3=0.0003$$

Figure A.3. Determination of the Probability Distribution for the A=3, S=2, N=6

Next the S=2 the match probability was generalized for any value of N. This is shown in the following decision tree (Figure A4).

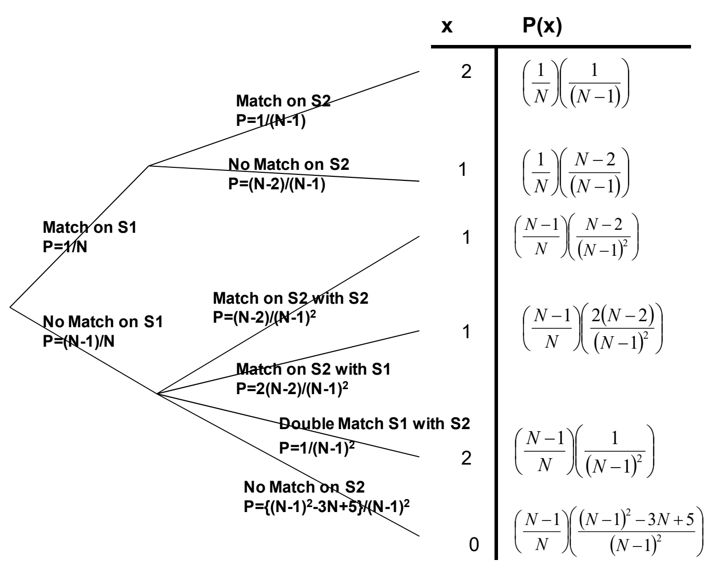


Figure A.4. Match Probability for Any Appraiser Pair and S=2 (Generalized on N)

The following expressions are developed based upon the probability expressions shown in the above decision tree (Figure A4).

$$P(X=0)=\left(\frac{N-1}{N}\right)\left(\frac{(N-1)^2-3N+5}{(N-1)^2}\right) \tag{A-2}$$

$$P(X=1)=\frac{4(N-2)}{N(N-1)} \tag{A-3}$$

$$P(X=2)=\left(\frac{1}{N}\right)\left(\frac{1}{N-1}\right)+\left(\frac{N-1}{N}\right)\left(\frac{1}{(N-1)^2}\right) \tag{A-4}$$

Therefore, making use of the above expression (i.e., equations A-2, A-3, and A-4) the probability distribution can be determined for the A=3 and S=2 situation across possible values of N. This is illustrated in the following Figure A5. A note of caution when analyzing the following probability distribution figures, the lines connecting the discrete points are only used as a reference. The value of the random variable (X) can only take on integer values; this is because X is the count of the number of pair-wise matches.

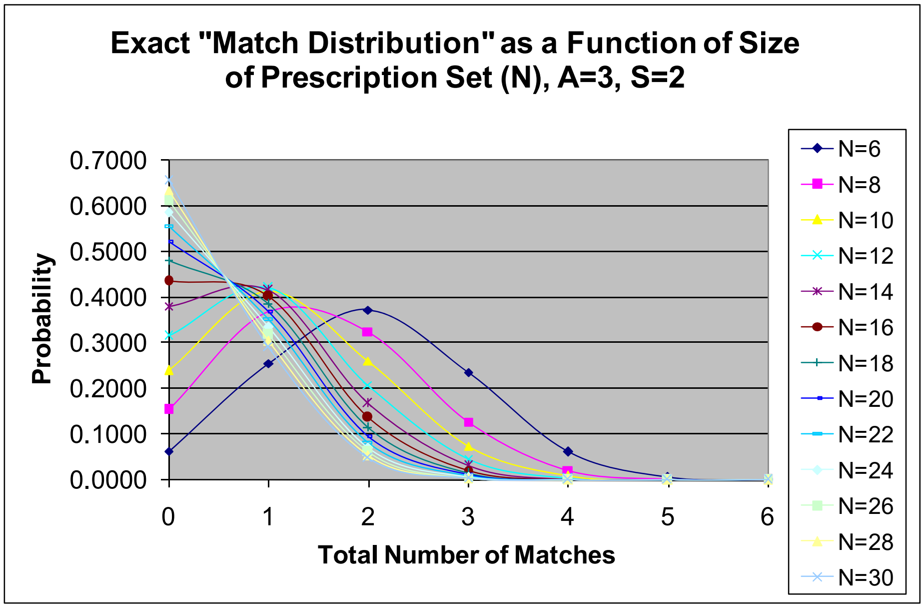


Figure A.5. Shape of the Probability Distribution A=3 and S=2

The case for S=3 is more difficult to determine. The simplest case was first developed where the size of the prescription set was limited to 6 (i.e., N=6). The decision tree which shows the match probability of any pair of appraisers is shown in the following Figure A6.

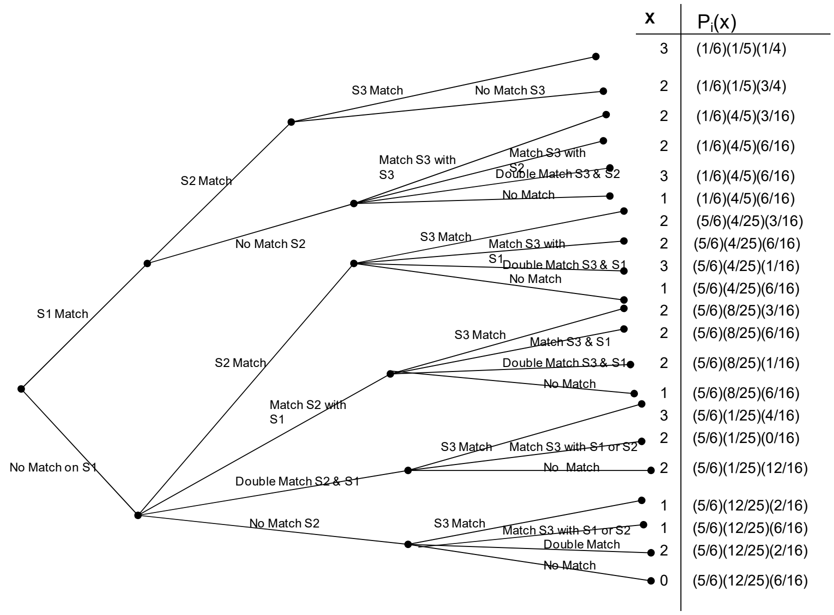


Figure A.6. Match Probability for any Appraiser pair (N=6, S=3).

Next, this result is extended for the three appraiser case (A=3). This is the situation where three appraisers are allowed to make three selections out of N=6 total prescription set. The following illustrates the determination of the probability distribution for this situation. The range of possible matches which can result from this experiment are from 0 to 9, where the maximum number of matches is determined as follows.

$$S\binom{3}{2} = 3 * (3) = 9$$

Therefore, the calculation of the exact probability distribution for A=3, S=2, and N=6 is determined as follows.

$P_0=0.15$ $P_1=0.40$ $P_2=0.4167$ $P_3=0.033$

$$P(X=0)=P_0^3=(0.15)^3=0.0034$$
$$P(X=1)=\binom{3}{2}P_1P_0^2=3(0.40)(0.15)^2=0.027$$
$$P(X=2)=\binom{3}{2}P_2P_0^2+\binom{3}{2}P_1^2P_0=3(0.4167)(0.15)^2+3(0.40)^2(0.15)=0.100$$
$$P(X=3)=P_1^3+2\binom{3}{1}P_1P_2P_0+\binom{3}{2}P_3P_0^2=(0.40)^3+6(0.40)(0.4167)(0.033)+3(0.033)^2(0.15)^2=0.216$$
$$P(X=4)=\binom{3}{2}P_2^2P_0+2\binom{3}{2}P_3P_1P_0+\binom{3}{2}P_2P_1^2=3(0.4167)^2(0.15)+6(0.033)(0.40)(.15)+3(0.4167)(0.40)^2=0.290$$
$$P(X=5)=2\binom{3}{2}P_3P_2P_0+\binom{3}{2}P_2^2P_1+\binom{3}{2}P_1^2P_3=6(0.033)(0.4167)(0.15)+3(0.4167)^2(0.40)+3(0.033)(0.40)^2=0.237$$
$$P(X=6)=\binom{3}{2}P_3^2P_0+P_2^3+2\binom{3}{2}P_1P_2P_3=3(0.033)^2(0.15)+(0.4167)^2+6(0.40)(0.4167)(0.033)=0.106$$
$$P(X=7)=\binom{3}{2}P_3^2P_1+\binom{3}{2}P_2^2P_3=3(0.033)^2(0.40)+3(0.4167)^2(0.033)=0.019$$
$$P(X=8)=\binom{3}{2}P_3^2P_2=3(0.033)^2(0.4167)=0.001$$
$$P(X=9)=P_3^3=(0.033)^3=0.000$$

Figure A.7. Determination of Exact Probability Distribution for S=3, A=3, and N=6

Thus, the probability distribution can be determined for the A=3 and S=3 situation across possible values of N. This is illustrated in the following Figure A8. The value of the random variable (X) can only take on integer values. This is because X describes the number of pair-wise matches.

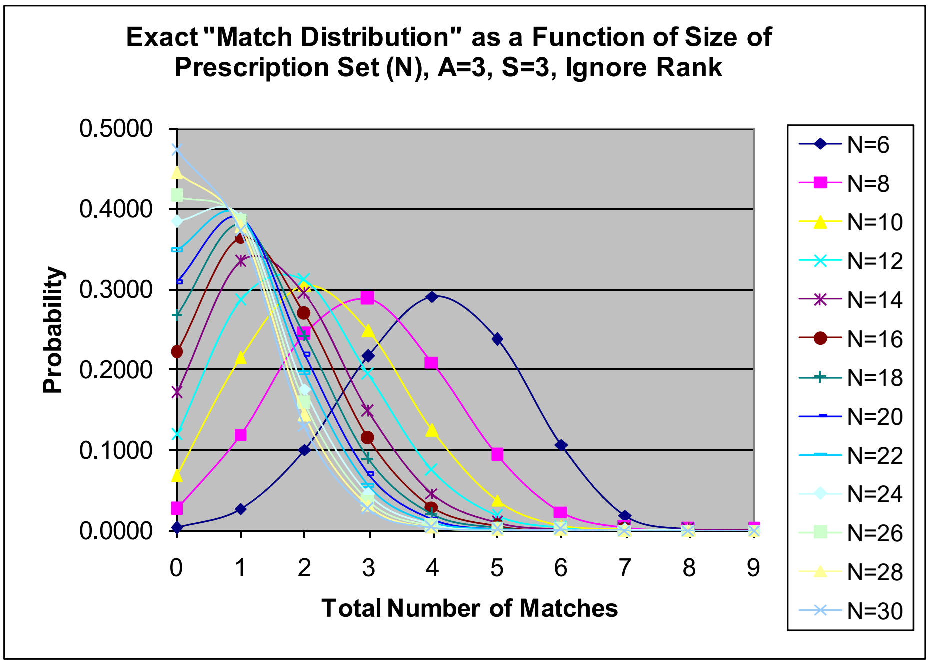


Figure A.8. Shape of the Probability Distribution A=3 and S=3

(note: lines connecting points are only used as references)

A3. Development of the Binomial Approximation

The exact probability distribution of the number of pair-wise matches was developed in the preceding section. This presents the exact number of matches under the null hypothesis conditions of the operation of pure chance causes. This was determined for any value of N, but for selected small values of A (i.e., A=2,3) and S (i.e., S=2,3). This section presents the use of the binomial distribution to approximate the actual probability distribution. The general expression of the binomial function is as follows.

$$P(x) = \binom{n}{x} \hat{p}^{x} (1 - \hat{p})^{n-x} \tag{A-5}$$

Where X and $\hat{p}$ are defined in the following manner. The response variable, X, is the number of pair-wise comparisons matches that result across A appraisers making S selections out of N available prescriptions. The binomial parameter, $\hat{p}$, is defined as the probability of a pair-wise match occurring. The challenge is in determining an effective estimate of $\hat{p}$ in terms of the problem parameters (i.e., A, S, and N). Several ways of estimating $\hat{p}$ were considered - the approach that worked the best is shown below.

$$\hat{p} \approx \frac{S + \binom{A}{2}}{2N + 1} \tag{A-6}$$

The following discussion shows that the above estimate for $\hat{p}$ works reasonably well for the small problem (i.e., A=2,3 and S=2,3). Other expressions for $\hat{p}$ may be found to work better, but the above expression was used as the basis for the statistical testing.

A4. Performance of the Binomial Approximation

The preceding sections have presented the exact solution for the small scale problem and have presented the binomial approximation as a reasonable method for approximating the actual probability distribution. This section focuses are illustrating how well the binomial method works for those small problems in which the exact probability distributions are known.

The approximation method is shown for various sizes of the prescription set (N). The simple three appraiser - two selection situation is shown in the Figure A9 across different values of N. As can be seen from the Figure A9, the approximation method appears to work reasonable well, especially for larger values of N.

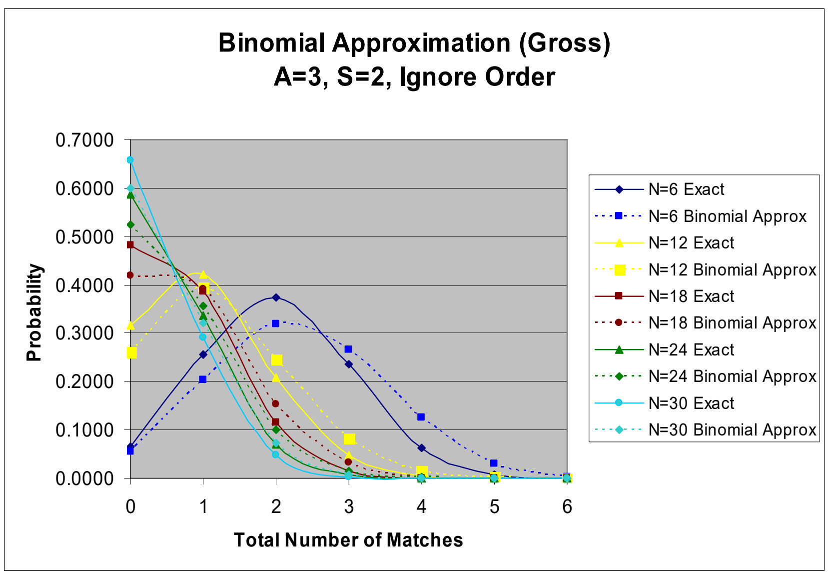


Figure A.9. Results of the Binomial Approximation for the A=3 and S=2 Situation

A similar result occurs when the effectiveness of the approximation is evaluated for the S=3 case. This situation also includes three appraisers and a defined size of the prescription set and is shown in the Figure A10.

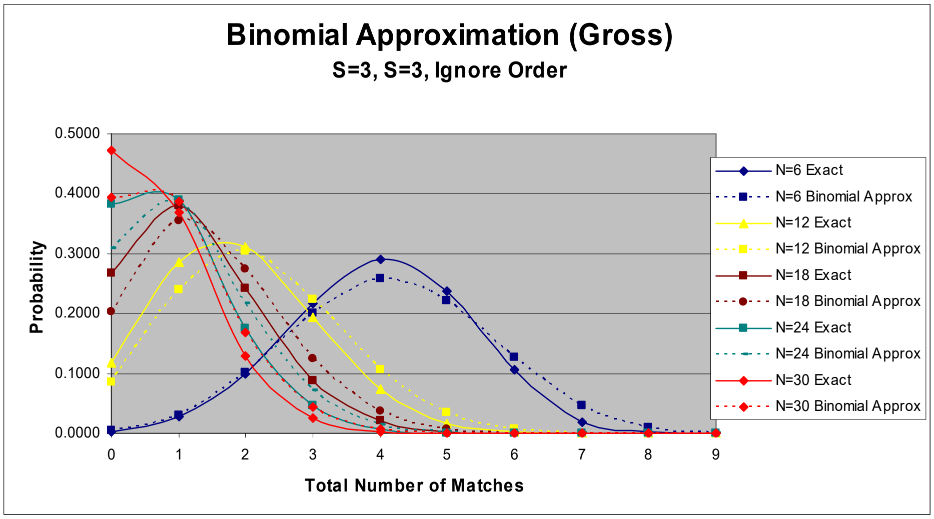


Figure A.10. Results of the Binomial Approximation for the A=3 and S=2 Situation

Therefore, the binomial approximation appears to work reasonably well in these particular small problem cases. In fact, it can be seen that the approximation generally improves for higher values of N and also appears to improve for increasing levels of X – given values of A, S, and N. It is the performance of the approximation in the region of increasing values of X that is of the most interest, since that is the region of concern when making judgments about whether or not the number of matches is consistent with the operation of chance causes or not. This result can be seen most clearly in the following Figures A11 and A12.

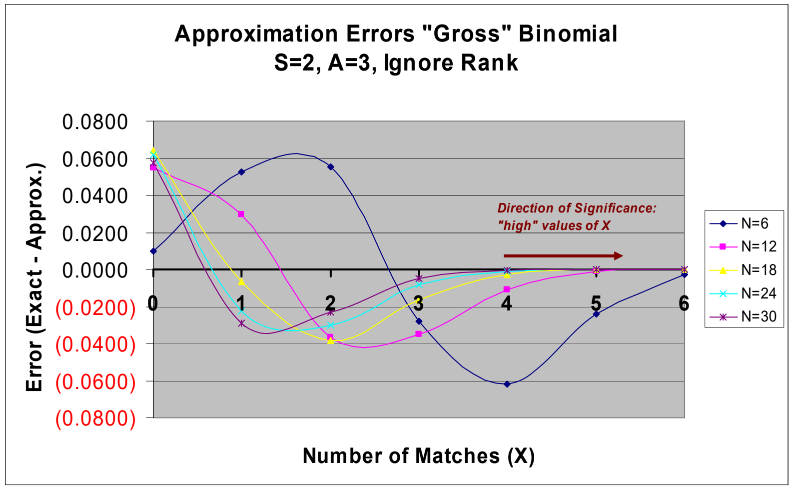


Figure A.11. Approximation Errors for the Situations where S=2 and A=3

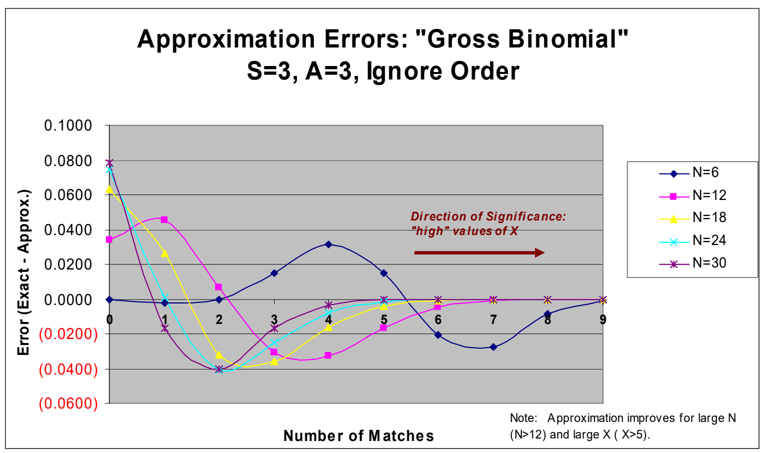


Figure A.12. Approximation Errors for the Situations where S=3 and A=3

A5. Approach to Significance Testing

The following illustrates the general approach for determining significance in terms of whether or not the number of matches observed is consistent with the operation of chance causes or not. The test of hypothesis outline is as follows.

H_O: Number of matches is random

H_1: Number of matches is not random

Parameters: number of appraisers (A), number of selected prescriptions allowed each appraiser (S), and the total number of possible prescriptions (N).

Random Variable: the total number of pair-wise matches (X)

It is shown in the appendix that the probability distribution of X (for small values of S and A approximately is approximated by the binomial function.

$$P(x) = \binom{n}{x} \hat{p}^{x} (1 - \hat{p})^{n-x}$$

where

$$\hat{p} \approx \frac{S + \binom{A}{2}}{2N + 1}$$

In this technical note the above approximation shown above has been shown to work reasonably well for small values of S and A. Some measure of caution should be used for larger values of S and A (i.e., S>3 and A>3) – since we do not know how well the approximation works in that region.

A6. Tables of Selected Probabilities for Use in Significance Testing

The following tables are provided in order to show results from the binomial approximation approach in the region of the experimental situation encountered by this research. In general the region of interest is defined by a relatively large N (i.e., N=91), high value of S (i.e., S=14, 15), and slightly larger values of A (i.e., A=2-6). The cumulative probability was used, which makes judging significance slightly easier than just providing the individual discrete probabilities.

Approximate Probability Distribution: Appraiser Consistency Problem

Number of Appraisers	A=	2	Appraisers: 2 (1-Panel Consensus, 1-Field)	
Total Prescription Set (N)	N=	91		
phat = (# of appraiser pairs+ # of selections) / (2N+1)				
Phat	***0.077***	***0.082***	***0.087***	***0.093***
Number of Selections (S)	13	14	15	16
Maximum number of Matches = S*[combin(A,2)]	13	14	15	16
Possible Matches(X)	**Cum. Prob**	**Cum. Prob.**	**Cum. Prob.**	**Cum. Prob.**
0	0.3554	0.3020	0.2535	0.2101
1	0.7380	0.6795	0.6178	0.5545
2	0.9283	0.8986	0.8621	0.8189
3	0.9860	0.9768	0.9636	0.9453
4	0.9980	0.9961	0.9927	0.9874
5	0.9998	0.9995	0.9989	0.9977
6	1.0000	0.9999	0.9999	0.9997
7	1.0000	1.0000	1.0000	1.0000
8	1.0000	1.0000	1.0000	1.0000
9	1.0000	1.0000	1.0000	1.0000
10	1.0000	1.0000	1.0000	1.0000
11	1.0000	1.0000	1.0000	1.0000
12	1.0000	1.0000	1.0000	1.0000
13	1.0000	1.0000	1.0000	1.0000
14		1.0000	1.0000	1.0000
15			1.0000	1.0000
16				1.0000

Figure A.13   Two Appraiser Case: Approximate Probability Distribution

Approximate Probability Distribution: Appraiser Consistency Problem

Number of Appraisers	A= 6		Appraisers: 6 Individual (5-Panel, 1-Field)	
Total Prescription Set (N)	N= 91			
phat = (# of appraiser pairs+ # of selections) / (2N+1)				
Phat	***0.153***	***0.158***	***0.164***	***0.169***
Number of Selections (S)	13	14	15	16
Total number of trials = S*[combin(A,2)]	195	210	225	240
Possible Matches(X)	**Cum. Prob.**	**Cumm. Prob.**	**Cum. Prob.**	**Cum. Prob.**
0	0.0000	0.0000	0.0000	0.0000
1	0.0000	0.0000	0.0000	0.0000
2	0.0000	0.0000	0.0000	0.0000
3	0.0000	0.0000	0.0000	0.0000
4	0.0000	0.0000	0.0000	0.0000
5	0.0000	0.0000	0.0000	0.0000
6	0.0000	0.0000	0.0000	0.0000
7	0.0000	0.0000	0.0000	0.0000
8	0.0000	0.0000	0.0000	0.0000
9	0.0000	0.0000	0.0000	0.0000
10	0.0000	0.0000	0.0000	0.0000
11	0.0000	0.0000	0.0000	0.0000
12	0.0001	0.0000	0.0000	0.0000
13	0.0002	0.0000	0.0000	0.0000
14	0.0005	0.0000	0.0000	0.0000
15	0.0011	0.0001	0.0000	0.0000
16	0.0023	0.0003	0.0000	0.0000
17	0.0047	0.0007	0.0001	0.0000
18	0.0088	0.0014	0.0002	0.0000
19	0.0159	0.0029	0.0004	0.0000
20	0.0271	0.0055	0.0008	0.0001
21	0.0440	0.0099	0.0016	0.0002
22	0.0681	0.0171	0.0031	0.0004
23	0.1009	0.0281	0.0057	0.0008
24	0.1433	0.0443	0.0100	0.0016
25	0.1958	0.0669	0.0167	0.0030
26	0.2577	0.0973	0.0268	0.0054
27	0.3277	0.1363	0.0415	0.0092
28	0.4036	0.1842	0.0618	0.0151
29	0.4825	0.2409	0.0889	0.0239
30	0.5615	0.3053	0.1235	0.0365
31	0.6373	0.3757	0.1663	0.0539
32	0.7076	0.4499	0.2171	0.0771
33	0.7703	0.5253	0.2754	0.1070
34	0.8242	0.5991	0.3399	0.1440
35	0.8690	0.6691	0.4089	0.1885
36	0.9050	0.7331	0.4804	0.2402
37	0.9330	0.7898	0.5520	0.2983
38	0.9540	0.8384	0.6214	0.3615
39	0.9692	0.8788	0.6867	0.4284
40	0.9800	0.9113	0.7462	0.4969
41	0.9873	0.9366	0.7988	0.5651
42	0.9922	0.9559	0.8441	0.6309
43	0.9953	0.9700	0.8818	0.6928
44	0.9973	0.9801	0.9124	0.7493
45	0.9984	0.9871	0.9366	0.7994
46	0.9991	0.9919	0.9551	0.8428
47	0.9995	0.9950	0.9689	0.8793
48	0.9998	0.9970	0.9790	0.9093
49	0.9999	0.9982	0.9861	0.9332
50	0.9999	0.9990	0.9910	0.9518
51	1.0000	0.9994	0.9943	0.9660
52	1.0000	0.9997	0.9965	0.9765
53	1.0000	0.9998	0.9979	0.9841
54	1.0000	0.9999	0.9987	0.9895
55	1.0000	1.0000	0.9993	0.9932
56	1.0000	1.0000	0.9996	0.9957
57	1.0000	1.0000	0.9998	0.9973
58	1.0000	1.0000	0.9999	0.9984
59	1.0000	1.0000	0.9999	0.9990
60	1.0000	1.0000	1.0000	0.9994
61	1.0000	1.0000	1.0000	0.9997
62	1.0000	1.0000	1.0000	0.9998
63	1.0000	1.0000	1.0000	0.9999
64	1.0000	1.0000	1.0000	0.9999
65	1.0000	1.0000	1.0000	1.0000
66	1.0000	1.0000	1.0000	1.0000
67	1.0000	1.0000	1.0000	1.0000
68	1.0000	1.0000	1.0000	1.0000
69	1.0000	1.0000	1.0000	1.0000
70	1.0000	1.0000	1.0000	1.0000
Continued ...				

Figure A.14 Two Appraiser Case: Approximate Probability Distribution

APPENDIX B

ROLE OF PORTER'S STRATEGIES WITHIN ASSESSMENTS

Appendix B - Role of Porter's Strategies within Assessments

B1. Introduction

The purpose of this paper is to provide a brief overview of Michael Porter's concept of generic strategies and to discuss their impact on the development of an assessment methodology of manufacturing firms. Porter's seminal publications on business strategy, Competitive Strategy (1980) and Competitive Advantage (1985), advance the theory of generic strategies. These strategies are intended to assist firms with obtaining a sustained competitive position within their industry. The purpose of manufacturing enterprise assessment is to utilize classification schemes, or taxonomies, to develop a set of recommendations which target improved manufacturing performance. The pursuit of improved performance must take into account how the firm intends to position itself competitively. Therefore, an important aspect of the manufacturing assessment is to determine the firm's strategy and evaluate the strategic fit of the firm's activities.

B2. Porter's Generic Strategies

It is difficult to underestimate Michael Porter's contribution to the current interest in business strategy. One researcher commented that Porter's work on generic competitive strategy was "unquestionably among the most substantial and influential contributions that have been made to the study of strategic behavior in organizations."[177] However, prior to discussing Porter's contribution it is important to understand what strategy means. One author notes that "strategy is the pattern or plan that integrates an organization's major goals policies and action sequences into

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[177] Campbell-Hunt Colin, "What have we learned about generic competitive strategy? A Meta-Analysis", Strategic Management Journal, 2000, Vol. 21, pp. 127-154

a cohesive whole."[178] Another author explains "strategy is defined as the way in which a corporation differentiates itself positively from competitors, using its relative corporate strengths and weaknesses to better satisfy company needs."[179] Porter enhances this understanding of strategy by commenting "Strategy is the creation of a unique and valuable position, involving a different set of activities. If there were only one ideal position there would be no need for strategy. … The essence of strategy is to choose activities that are different from rivals."[180] .

Porter argues that there are fundamentally two types of competitive advantage that firms can achieve: cost leadership and differentiation. These advantages when combined with the firm's target scope result in three generic strategies: *cost leadership*, *differentiation*, and *focus*. Porter claims that successful companies use variations of these basic strategies in order to develop a sustainable advantage. Firms that fail to embrace some form of these generic strategies find themselves in the unfortunate position of trying to compete on all dimensions simultaneously. Porter refers to this as the "stuck in the middle" strategy, which leads to a weakened competitive position.

Each of these generic strategies is different paths to obtaining advantage. Cost leadership and differentiation are options regarding the type of advantage sought and the scope references the domain in which the firm has decided to compete. One way of thinking about Porter's strategies is they reflect a firm's choices in two basic dimensions: competitive advantage and market scope. The firm's market scope is either focused on particular types of customers or market segments while some firms choose to focus industry wide. Some have found it helpful to

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[178] James Brian Quinn in The Strategy Process: Concepts and Contexts, as quoted in website article on entitled "Strategy", www.referenceforbusiness.com/small/Sm-Z/strategy.html, 3/18/06

[179] Kenichi Ohmae in the book The Mind of the Strategist, as quoted, in website article on entitled "Strategy", www.referenceforbusiness.com/small/Sm-Z/strategy.html, 3/18/06

[180] Porter, Michael, E., "What is Strategy?", Harvard Business Review, Harvard Business School Publishing Corporation, November-December 1996, pp. 8.

think of Porter as four distinct strategies, instead of three. Porter's second book refers to focus, the third strategy, as having two aspects (i.e., cost and differentiation), which leads some to conclude that Porter actually advocates four strategies. Thinking of the strategies in two dimensions with each dimension having two levels is a helpful way to understand Porter's concept. This approach is summarized in Figure 1 below.

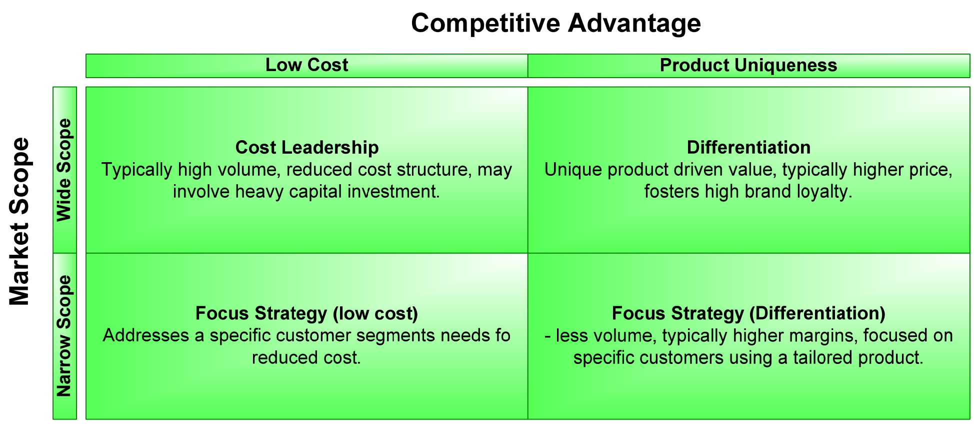

Figure B.1. Porter's Generic Competitive Strategies

In order for a firm to establish a strong position, it must provide customers with a product which has an attractive value proposition; the firm must either deliver higher value than its competitors or provide comparable value at a lower cost. This advantage should be achieved in such a way that it is sustainable (i.e., not easily replicated by rivals).

Cost Leadership:

The driving characteristic underlying this strategy is the firm's quest for becoming or remaining the industry's low cost producer. This requires that every activity must be carefully scrutinized with respect to cost. Also investments in leading technologies are often required to maintain a low-cost position, which makes this strategy particularly difficult for smaller manufacturers. This cost leadership is often enabled by a firm's dominate market size and related scale of operations. "Low cost producers typically sell a standard or no frills product and place considerable emphasis on reaping scale and absolute cost savings."[181] If a firm is the cost leader and still able to command prices close to or even slightly below industry average then this translates into high returns. However, if the firm's product is no longer viewed as on par with its competitors then deep price discounting may result, which degrades its competitive position. Another difficulty associated with this strategy is that the firm might become so inwardly focused that changes in the market are not detected (e.g., introduction of new products). However, difficult for a firm to achieve, the cost advantage can lead to "strong market share and profit margins."[182]

Differentiation:

The basis of this strategy is for the firm to offer a product that provides unique value with respect to product attributes which are important to customers. "The logic of the differentiation strategy requires that a firm choose attributes in which to differentiate itself that are different from its rivals."[183] The product attempts to attract customers with a product that satisfies their needs better than the competitors. This type of product typically justifies a higher price and greater margin. The source for differentiation may come from a variety of sources: the product, the delivery system, the marketing approach, etc. However the cost to achieve the differentiation should not exceed the premium pricing that the differentiation commands. A high market share is generally not a compatible goal for firms which adopt this strategy. A firm following this strategy can't ignore costs, because its premium pricing can be nullified by an inordinately high cost

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[181] Michael E. Porter, Competitive Advantage, The Free Press, New York, New York, 1985, pp. 13.

[182] Strategy, www.referenceforbusiness.com/small/Sm-Z/strategy.html, Business Reference: Encyclopedia of Small Business.

[183] Michael E. Porter, Competitive Advantage, The Free Press, New York, New York, 1985, pp. 13.

structure. The concern is to prevent competitors from offering a "me to" product at a lower price. This position, if obtained, produces brand loyalty and high margins.

Focus:

"This strategy is quite different from the others because it rests on a narrow competitive scope within the industry. The focuser selects a segment or group of segments in the industry and tailors its strategy to serving them to the exclusion of others."[184] The objective is for the firm to focus on serving their particular markets better than competitors in terms of either product differentiation, or low cost. These types of opportunities often emerge when a larger industry rival does not serve particular industry segments very well. If competitors "over-perform" in the target market then this opens up the possibility for the firm to establish a cost advantage (i.e., focus strategy – low cost). However, if on the other hand, the dominate industry players "under-perform" in the target market then the firm has an opportunity to exploit this gap by delivering unique product value (i.e., focus strategy – differentiation).

Stuck in the Middle:

According to Porter, a firm which attempts to "be all things to all people" runs the risk of being relevant to none. This characterizes firms that strive to create an advantage using each of the generic strategies. The result is that their rivals, if they are following one of the generic strategies, will be better positioned to compete. This position often stems from a firm's "unwillingness to make the hard choices about how to compete."[185] Interestingly, even successful firms can find themselves in this situation, if they compromise their generic strategy for the sake of growth. Sometimes these firms remain profitable, particularly in highly profitable industries.

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[184] Michael E. Porter, Competitive Advantage, The Free Press, New York, New York, 1985, pp. 15.

[185] Michael E. Porter, Competitive Advantage, The Free Press, New York, New York, 1985, pp. 17

B3. Relationship to Assessment of Manufacturing Firms

Based upon a review of assessment methodologies, there is a tendency to place more emphasis on the things that are easily observable (i.e., operations) and overlook the things that are not as easily seen (i.e., strategy). Porter's work on strategy clearly indicates that there should be a strong relationship between the firm's strategy and its supporting operations, and therefore it is imperative for the assessment methodology to include the impact of the firm's strategy.

Link Between Strategy and Operations

Strategy provides insight in terms of *how* the firm chooses to deliver value to customers within in its market. The translation of strategy to operations includes decisions (i.e., trade-offs) made by the firm in such a way to support the firm's competitive position. Driven by a particular strategy a firm may choose to invest in different activities than their rivals, or perform the same activities in a unique or different manner. Therefore, Porter advocates that at its roots competitive strategy is about being *different*: "deliberately choosing a different set of activities to deliver a unique mix of value."[186]

Since strategy drives actions within the firm, it therefore has consequences on skills, resources, and capabilities of the company. This clearly impacts the entire organization. "Strategic positioning sets the trade-off rules that define how individual activities will be configured and integrated. Seeing strategy in terms of activity systems only makes it clearer why organizational structure, systems, and processes need to be strategy specific"[187]

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[186] Porter, Michael, E., "What is Strategy?", Harvard Business Review, Harvard Business School Publishing Corporation, November-December 1996, pp. 4.

[187] Porter, Michael, E., "What is Strategy?", Harvard Business Review, Harvard Business School Publishing Corporation, November-December 1996, pp. 15.

One of the strongest advantages comes from the way activities fit and re-enforce each other. In companies with good strategy the result is activities complement each other in such a way as to create value. For example, the cost (or customer value) associated with one activity is lowered (or increased) because of the way other related activities are performed. "It is harder for a rival to match an array of interlocked activities than it is merely to imitate a particular sales force approach, match a process technology, or replicate a set of product features."[188]

Strategy & Operational Effectiveness

According to Porter, many managers often confuse operational effectiveness (OE) efforts (e.g., TQM, lean manufacturing) with strategy. Porter, while recognizing the importance of improving operations, draws a hard distinction between OE and strategy. "In some sense, strategy is the antithesis of best practice competition, Rather than trying to run the same race faster, strategy is about choosing to run a different race."[189] In fact, Porter claims, after impressive results over the last couple of decades, a strategy which focuses exclusively on OE ultimately faces diminishing returns. OE, in absence of strategy, results in leading companies down the path of mutually destructive competition.[190] This is as a result of "zero sum competition, static, or declining practices, and pressures on costs that compromise companies' ability to invest in the business for the long term."[191]

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[188] "The Importance of Being Strategic", A Summary of the remarks by Michael E. Porter, Bishop William Lawrence University professor, Harvard Business School, given at the Balanced Scorecard Collaborative at the recent North American Summit, 2002 Harvard Business School Publishing Corporation, pp. 15.

[189] "The Importance of Being Strategic", A Summary of the remarks by Michael E. Porter, Bishop William Lawrence University professor, Harvard Business School, given at the Balanced Scorecard Collaborative at the recent North American Summit, 2002 Harvard Business School Publishing Corporation, pp. 4.

[190] Porter, Michael, E., "What is Strategy?", Harvard Business Review, Harvard Business School Publishing Corporation, November-December 1996, pp. 2.

[191] Porter, Michael, E., "What is Strategy?", Harvard Business Review, Harvard Business School Publishing Corporation, November-December 1996, pp. 4.

According to Porter, very few companies have competed successfully on the basis of operational effectiveness for a sustained period of time. In answering the question about why OE is not strategy, Porter offers the following.

- Rapid dissemination of best practices provides relative improvement to no one.
- Competitive convergence resulting from ERP, benchmarking, and outsourcing. The more generic these activities become and the less apt they are to be a source of competitive advantage.

Porter's following statement, published in 1996, appears now to be somewhat prophetic. "After a decade of gains in operational effectiveness, many companies are facing diminishing returns. Continuous improvement has been etched on manager's brains. But its tools unwittingly draw companies toward imitation and homogeneity."[192] Anecdotal evidence from the financial performance of Shingo Prize Award winners appears to bolster Porter's argument. The Shingo Prize - awarded annually to plants which demonstrate world class levels of practice and performance in terms of lean manufacturing – has come under recent critique based upon the financial performance of many of its winners.[193] Almost one third of the awards during the last 5 years (1991-1995) have been to plants belonging to Delphi, which recently filed for bankruptcy. According to a recent web blog, an analysis of a fictitious fund portfolio comprised of only of Shingo Award winners resulted in a -75% return: even after eliminating Delphi the return was

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[192] Porter, Michael, E., "What is Strategy?", Harvard Business Review, Harvard Business School Publishing Corporation, November-December 1996, pp. 4.

[193] "Delphi's Shingo Prizes can't save it from bankruptcy" Manufacturing and Technology News, October 28, 2005, V12., Issue 19, p. 5

still -55%.[194] This provides strong evidence that *sustained performance is not solely a function of operational effectiveness.*

Porter, while critical of those that view OE as the only ingredient needed to achieve sustained competitive advantage, does not diminish the importance of operational excellence. In Porter's opinion, OE is a necessary though not sufficient condition to achieving a competitive advantage. "Are operational effectiveness and strategy mutually exclusive? Of course not. Both are essential. A company has to keep improving and assimilating best practices; if not it will fall behind. At the same time, you have also got to maintain your strategic distinction – defining, refining, enhancing how you are different"[195]

B5. Specific Impact on Assessment Research

Clearly, a full orbed assessment of the enterprise must include the firm's understanding of its strategy, or lack of it. If defined strategy exists, then a critical aspect of the assessment is to evaluate how well the firm's structure, policies, and operations align with the firm's strategy. Porter's generic strategies provide an effective framework for classification of strategy within the proposed Manufacturing Enterprise Taxonomy.

The identification of the firm's strategy early in the assessment provides the assessor with a prism from which to view the entirety of its operations. This approach is in alignment with Porter's argument that effective strategy is accomplished by a coordinated fit with and between

[194] "Shingo Investing: a Loosing Bet", Lean Blog, http://kanban.blogspot.com/2006/03shingo-investing-losing-bet.html, Thursday, March 9, 2006.

[195] "The Importance of Being Strategic", A Summary of the remarks by Michael E. Porter, Bishop William Lawrence University professor, Harvard Business School, given at the Balanced Scorecard Collaborative at the recent North American Summit, 2002 Harvard Business School Publishing Corporation, pp. 4.

activities. Once the firm's strategy is known, then this provides perspective for the evaluation of various operations within the company. This relationship is depicted in Figure B2.

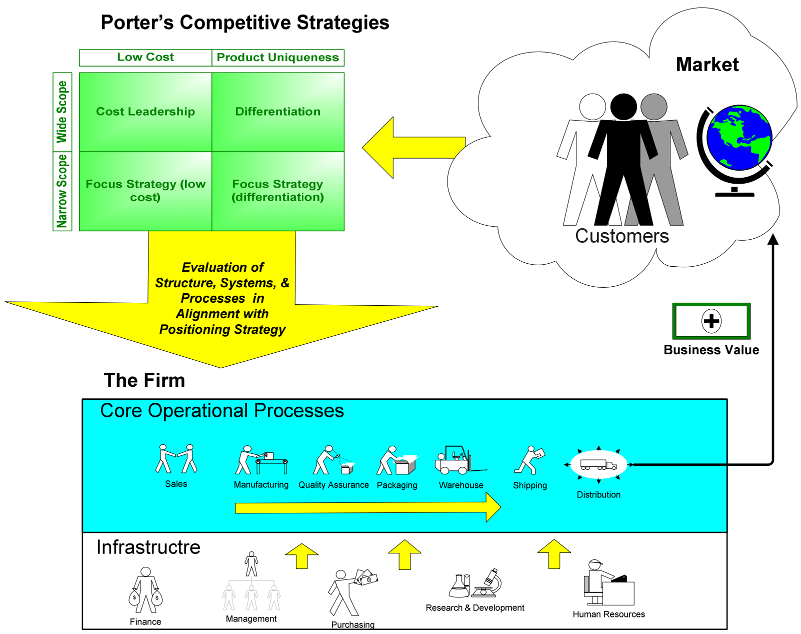

Figure B.2. Role of Porter's Generic Strategies in Assessments

It would seem that the firm's strategy gives rise to the relative importance of various dimensions of enterprise performance (e.g., cost, quality, delivery, flexibility, …). Clearly, all aspects of performance matters, however the relative importance of each dimension would seem to be a function of the firm's strategy. Hopp and Spearman (2001) note the following.

> "Today, the importance of operations to the health, and even viability, of manufacturing firms is greater than ever due to global competition in the following three dimensions:
>
> - Cost. This is the traditional dimension of competition that has always been the domain of operations management. ….

- Quality. The 1980s brought widespread recognition that quality is a key competitive weapon.
- Speed. While cost and quality remain critical, the 1990's can be dubbed the decade of speed. Rapid development of new products, coupled with quick customer delivery, is pillars of time-based competition strategies that have been adapted by leading firms in many industries.

These three dimensions are broadly applicable to most manufacturing industries, but their relative importance obviously varies from one firm to another." [196]

In a sense, the firm's strategy gives shape to the firm's desired performance profile. One complicating factor is that according to the literature these dimensions of performance are not generally acquired independently. For example, numerous researchers have shown and practitioners can testify that quality and cost are not independent dimensions of performance. In fact, the leading thought among most manufacturing experts is that it is dangerous to pursue cost reduction without first improving quality (Schonberger - 1986, Ferdows and DeMeyer, -1990). Several theories have appeared in the literature, which attempt to define these relationships (e.g., world class view, sand cone model, and Skinner's trade-off model). Empirical investigations should be conducted to examine the performance profile regarding firms which are engaged in following one of Porter's generic strategies.

Despite difficulties mapping Porter's generic strategies to dimensions of operating performance in a general manner, this may be done logically on a specific case basis. In fact. Kaplan and Norton's Balanced Scorecard was developed in order to assist firms in just this type of strategy deployment. For example, a firm which is facing overseas competition in a market

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[196] Hopp & Spearman, Factory Physics: Foundations of Manufacturing Management, 2001, McGraw Hill, 2nd Edition, pp. 5

which is primarily domestic (e.g., furniture industry) may not desire to compete on the basis of cost. The firm may choose instead to leverage proximately to market by committing to a quick response capability and providing value to their customers by enabling lower inventory levels. In this example costs are not unimportant, in fact cost reductions that do not degrade the firm's ability to compete in other dimensions are always advantageous. However, in this example, the firm's performance in terms of flexibility and speed are strategic imperatives.

From the perspective of the assessment, we need to have a clear understanding of what strategy looks like deployed within a company. Of particular assistance in this regard is Kaplan and Norton's work on the Balanced Scorecard. The Balanced Scorecard essentially a methodology for showing firms how to translate strategy into action. [197]

How does the notion of Porter's generic strategies impact the assessment, if no real discernable strategy is evident? Porter describes this as a "stuck in the middle" strategy where the firm tries to be "all things to all people" which he argues leads to a weakened competitive position. In those cases one of the recommendations from the assessment may be for the firm to develop a strategy. The development of a proper strategy for the firm is out of the scope of the assessment process, but identifying the need for the firm to define and to commit to a strategy is certainly germane to the assessment. However, even if no strategy is clearly defined, then other recommendations from the assessment may still provide value with respect to OE. Porter's advice for these firms merits observation.

> "The firm stuck in the middle must make a fundamental strategic decision. Either it must take the steps necessary to achieve cost leadership or at least cost parity, which usually involves aggressive investments to modernize and perhaps the necessity to buy market share, or it must orient itself to a particular target (focus) or achieve some

[197] Robert. S. Kaplan and David P. Norton, The Balanced Scorecard: Translating Strategy into Action, Harvard Business School Press, Boston, Massachusetts, 1996, pp. 37.

uniqueness (differentiation). … The choice among these options is necessarily based upon the firm's capabilities and limitations. Successfully executing each generic strategy involves different resources, strengths, organizational arrangements, and managerial style, as has been discussed. Rarely, is a firm suited for all three. …. This choice (i.e., which of the three generic strategies is appropriate for the firm) rests on picking the strategy best suited to the firm's strengths one and least replicable by competitors."[198]

In conclusion, it is hypothesized that a firm's competitive advantage, which gives rise to Porter's generic strategies, are linked to important elements within the proposed manufacturing enterprise taxonomy (MET). The information presented below, though speculative, reflect the relationship between a firm's source of competitive advantage and its fit within the MET. The relationships need to be empirically tested in order to validate. Observations concerning some of these relationships are likely to arise during case studies within the proposed research.

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[198] Michael E. Porter, Competitive Strategy: Techniques for Analyzing Industries and Competitors, The Free Press, 1980, pp. 42

Selected Taxons	Porter's Source of Competitive Advantage	
	Cost Leadership	**Differentiation**
Performance Measures	Market penetration, operating cost, internal quality, asset utilization, low inventory levels, tight controls	Repeat customers, share of customers business,
Product Characteristics	Focus on standardization, manufacturability, high volume/low complexity, vertically integrated	Low volume/high complexity relative to its industry
Process Characteristics	Automated, speed valued over flexibility, capital intensive process.	Set-up intensive, capacity availability required to deal with product variations
Operations	Standardization, V-plant	A-plant, T plant,
Human Resources	Tendency for training to be task specific, learning curve emphasis	Values innovation

Figure B.3. Porter's Strategy and Selected MET Taxons

APPENDIX C

BOLDEN'S MODIFIED TAXONOMY (PST)

APPENDIX C – Production Systems Taxonomy

Modification of Bolden's Taxonomy (Bolden, et. al., 1997)

A. Emphasis on Improving Quality

1. Design and Production

1.A-1 *Quality standards*: Quotable national and international quality standards, such as BS 5750, BS 7750, ISO 9001 and QS 9000, which aim to standardize production processes so as to maintain a consistent level of quality.

1.A-2 *Statistical process control* (SPC, including statistical quality control SQC): The use of statistical methods to control quality.

1.A-3 *Total productive maintenance* (TPM, including total productivity management): Training machine operators to carry out preventive maintenance and minor repairs.

1.A-4 *Quality function deployment* (QFD, including quality function audits, QFA, and design for reliability, DFR): "A method for developing a design quality aimed at satisfying the consumer and then translating the consumer's demand into design targets and major quality assurance points to be used throughout the production phase … (QFD) is a way to assure the design quality while the product is still in the design stage".

1.A-5 *Mistake Proofing:* Designing products and production processes such they eliminate or reduce the risk of making mistakes, e.g. Poka-Yoke and zero quality control (ZQC).

2. Inventory and Stock

2.A-1 Supply chain partnering (including supply chain management, SCM): The development of mutually beneficial partnerships with suppliers to improve quality and compatibility.

2.A-2 Customer feedback: Obtaining formal feedback on product quality and performance from customers

2.A-3 Conformance checks: Continual or random testing of the quality of goods inwards and goods outwards.

3. Work Organization

3.A-1 Quality improvement teams (QITs, including quality control circles, QCCs): Usually a team of people from the same work area who meet on a regular basis to identify and solve their work-related problems.

3.A-2 Operator responsibility for quality: Giving operators' responsibility for the quality of their work, rather than making this the sole responsibility of the quality/testing department or senior staff; this often includes giving operators the right to stop production if quality is sub-standard.

3.A-3 Quality feedback to operators: Giving continual quality performance feedback to operators, for example in terms of scrap and defect rates.

3.A-4 Quality training: Training all operators in quality, e.g. error training, raised awareness and encouraging the application of quality procedures.

3.A-5 Ergonomic design: Designing products and production processes such that they minimize human error and enhance quality

4. Wider Organization

4.A-1 Total quality management (TQM, including Kaizen, continuous improvement, total improvement management (TIM) and total participation): "TQM is an approach to improving the competitiveness, effectiveness and flexibility of a whole organization. It is essentially a way of planning, organizing and understanding each activity, and depends on each individual at each level".

4.A-2 Quality awards: A range of quality awards, which while quotable are used more frequently as a model of best practice against which to develop quality improvement programs, e.g. Malcolm Baldrige National Quality Award (MBNQA), Deming Award, and European Quality Award (EQA).

4.A-3 Internationally Competitive Benchmarking for quality: Comparing a company's quality and performance against the best practice and performance of leading companies both within and outside the industrial sector.

B. Emphasis on reducing cost

1. Design and Production

1.B-1 Reduce work in progress: Reducing the quantity of materials being processed at any one time, for example, through reduced lot and batch sizes.

1.B-2 Just-in-time production (JIT, including make to order, MTO)*:* "The JIT idea is simple: produce and deliver finished goods just in time to be sold, sub-assemblies, and purchased materials jut in time to be transformed into fabricated parts".

1.B-3 Process mapping: Monitoring and planning the passage of materials through the manufacturing process to minimize wastage, e.g. process visualization, role activity diagram (RADs), flow diagrams, process modeling, and process flow analysis (PFA).

1.B-4 Design for Manufacturability: Designing products for ease of production and minimal waste*,* e.g. design for manufacturability (DFM*).*

1.B-5 Reusability: Reusing waste materials, e.g. object oriented programs (OOPS), recycling, and material recovery opportunities (MRO).

1.B-6 Value Engineering Rationalizing product design to reduce unnecessary components, e.g. bullet-train thinking.

2. Inventory and Stock

2.B-1 *Reduce inventory:* Reducing stores and buffer stocks, e.g. buffer management.

2.B-2 Single sourcing: Agreeing preferred supplier status to obtain reduced costs in terms of costs and administration.

2.B-3 Just-in-time inventory control (JIT): Purchasing raw materials only when required in order to reduce the need to maintain stock levels. Uses "pull" techniques such as Kanban to monitor the state of production and hence the need for new materials.

2.B-4 Forecasting: Predicting stock requirements in advance so that costs can be anticipated, e.g. material requirements planning (MRP) and use of market statistics to determine purchasing.

2.B-5 Logistics management: Managing internal and external logistics, e.g. integrated logistic support (ILS), operational research, and computer aided logistic support (CALS).

3. Work Organization

*3.B-1 Downsizing (*including "rightsizing"): Reducing costs by cutting back the size of the workforce.

3.B-2 De-layering: Reducing middle management positions by increasing the responsibility of operations or senior managers.

3.B-3 Outsourcing: Sub-contracting business processes to external agents.

3.B-4 Flexible Labor: Reducing labor costs by reducing the proportion of permanent, full-time staff and replacing them with part-time or temporary employees.

4. Wider Organization

4.B-1 Lean production (including lean production systems, LPS): "….transferring indirect tasks (including a substantial portion of what used to be called "management") to the primary work team while linking the efforts of the teams working on a product so that the product moves quickly and without interruption from design to production launch and from raw materials into the hands of the customer."

4.B-2 Cost management: Following a philosophy of cost reduction through practices such as cost accounting, activity based costing (ABC) and life-cycle costing.

4.B-3 Financial performance measures: Monitoring performance in terms of financial and productivity-related measures only, e.g. key performance indicators (KPIs), goal-based management, and annual turnover.

4.B-4 Time-based management: Regarding time as a commodity and arranging production so as to maximize effective use of time, e.g. time compression.

4.B-5 Benchmarking for costs: Learning from the best practice of industry leaders in terms of costs.

4.B-6 Balanced Scorecard: BSC is a framework for firms to develop an integrated set of performance measurements based upon the four perspectives (i.e., customer, internal, learning and growth, and financial). It serves as a link connecting strategy to action plans.

4.B-7 Link Manufacturing to Strategy: the need to strategically link the performance of manufacturing operations with the overall strategy and direction of the enterprise.

C. Emphasis on reducing cost

1. Design and Production

1.C-1 Rapid prototyping: Rapid design and prototyping via techniques such as rapid application development (RAD).

1.C-2 Concurrent engineering (including simultaneous engineering): "Concurrent engineering is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacturing and support" (Institute for Defense Analysis),

1.C-3 Customer involvement in product design: Involving customers in the designing and testing of new products, e.g. customization, and "envoys and milkmen".

1.C-4 Lead time reduction: Increased speed to market via faster design and development, and reduced change-over time.

1.C-5 Agile manufacture: Flexible and responsive manufacturing processes.

1.C-6 Single Minute Exchange of Die (SMED): Quick change methodology for reducing machine set-up time and enabling reduced batch sizes and greater customer responsiveness.

2. Inventory and Stock

2.C-1 Predicting customer requirements: Improving service by forecasting customer requirements in advance.

2.C-2 Maintaining stock levels: Maintaining stores of raw materials and finished goods so that they can be assembled and delivered to customers without delay.

3. Work Organization

3.C-1 Flexible work organization: Designing jobs and processes so that product type and mix can be changed quickly as and when required.

3.C-2 After-sales support: Providing support and assistance to customers once they have bought the product.

3.C-3 Cellular manufacture (including modular manufacturing): Organizing the shop floor such that an operator or group of operators has the resources to produce an entire or substantial part of the finished product.

4. Wider Organization

4.C-1 Customer Focus: A company-wide priority of service to customers; "the customer is always right".

4.C-2 Market research: Keeping up to date with demands and innovations in the market.

4.C-3 Customer surveys: Monitoring customer demands and customer satisfaction through regular surveys.

4.C-4 Benchmarking for customer responsiveness: Learning from the best practice of leading companies in terms of responsiveness to customers.

4.C-5 Business process re-engineering (BPR, including business process management, BPM, and business process redesign, BPRD): "BPR is the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service and speed". Uses processes such as value-added analysis.

D. Emphasis on improved technology

1. Design and Production

1.D-1 Computer aided process planning and control: A range of systems and techniques including: computer aided manufacturing (CAM), computer aided production management (CAPM), computer numerical control (CNC), and computer aided production planning (CAPP), expert systems, hybrid systems, fuzzy logic, artificial intelligence and neural networks.

1.D-2 Computer integrated manufacturing systems: (including computer integrated manufacturing (CIM), optimized production technology (OPT) and optimization):"CIM refers to the potential for a truly integrated manufacturing effort from product conception and design right through to assembly and after sales service using a common system and a common database".

1.D-3 Automation: Automated production processes, e.g. robots, automated guided vehicles (AGVs), and continuous process technology (CPT).

1.D-4 Computer aided design and engineering: A series of design and engineering tools such as in computer aided design (CAD), computer aided engineering (CAE), computer aided software engineering (CASE), computer simulation, mathematical modeling , and virtual reality.

1.D-5 New Process Development: The set of best practices associated with developing new products rapidly and effectively.

2. Inventory and Stock

2.D-1 Automated storage and retrieval systems (ASRS): Mechanized stock management systems.

2.D-2 Electronic data interchange (EDI): On-line computerized links to customer stock levels to enable planning distribution.

3. Work Organization

3.D-1 Flexible manufacturing systems (FMS): Computer integrated systems which have the flexibility to rapidly change product type and mix.

3.D-2 Group technology (GT): The associated hardware and software for cellular manufacturing.

3.D-3 Computer supported co-operative work (CSCW): Using computers to aid communication and co-operation, e.g. distributive computing, groupware, teleworking, and the Internet.

3.D-4. Manufacturing resources planning (MRP/ERP): A computer-based system for the planning and allocation of work among employees.

4. Wider Organization

4.D-1 Technology strategy for entire company: Following a strategy of increased technology and information technology (IT) use for the whole company.

4.D-2 Computer based management tools: Information systems to aid management decisions and information access, e.g. decision support systems (DSS), failure mode effects analysis (FMEA), management execution systems (MES) and management information systems (MIS).

4.D-3 Benchmarking for technology: Leaning form the best-practice of industry leaders in their use of technology and IT.

4.D-4 Environmental Compatibility: Ensuring environmental compatibility in terms of all processes and products.

4.D-5 Six Sigma: An advanced problem solving methodology and management approach that relies heavily upon achieving breakthrough levels of increases in quality often relying upon a range of statistical techniques.

E. Emphasis on employee development

1. Design and Production

1.E-1 Job rotation: Regularly rotating operators between different tasks.

1.E-2 Multi-skilling: Training operators to be able to carry out a range of tasks rather than a single one.

1.E-3 Psychometrics: Recruiting and promoting staff on the basis of their measured psychological and behavioral characteristics rather that simply on existing experience and qualifications.

1.E-4 Appraisal: Regularly appraising employees on a range of dimensions.

1.E-5 Training and development: Continual training and development of staff, e.g. identifying training needs, mentoring, professional up-dating, employee development, lifelong learning

1.E-6 Suggestion schemes: Giving staff the opportunity to provide suggestions as to improvements, without risking their job security.

1.E-7 Attitude surveys: Regularly measuring the attitudes of staff, and taking steps to increase employee wellbeing and effectiveness in response to survey findings.

1.E-8 Staff Management Rotation: Allowing staff the opportunity to work in other areas of the organization to increase their skills and understanding of the organization as a whole.

1.E-9 Safety management: Training all staff in safety and having safety as a key criterion for reward or punishment.

2. Inventory and Stock

2.E-1 Product team responsibility for purchasing and distribution: Giving product teams the autonomy to purchase materials and distribute finished products.

3. Work Organization

3.E-1 Reduce Status Barriers (including single status agreements): Reducing differences in working conditions and benefits between management and shop floor staff, e.g.

making hourly staff salaried, long-term employment opportunities for all, not allowing preference for parking spaces, etc.

3.1-2 Team-based work (including team working, cross-functional teams and autonomous work groups): "A distinguishable set of people who interact, dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, and who have each been assigned specific roles or functions to perform, and who have a limited life-span of membership".

3.E-3 Job enrichment: Making jobs more varied and demanding of extra skill, e.g. basing production on entire products rather than single processes.

3.E-4 Boundary management: Managing and communicating between functions and departments, e.g. using liaison personnel, cross0functional teams and task forces.

4. Wider Organization

4.E-1 Explicit company HRM strategy: Having employee development as a key component of the company's vision.

4.E-2 Employee empowerment: An overall philosophy of handing responsibility and decision making to employees lower down in the organization.

4.E-3 Performance-related pay: Encouraging and rewarding individual and team performance by related pay and benefits, e.g. individual and group bonuses, employee share offers and performance-related perks.

4.E-4 Culture change: Managing a change in corporate culture to increase employee involvement and motivation, e.g. change management and climate changes.

4.E-5 Learning climate (including learning company/organization): "A learning company is an organization that facilitates the learning of all its members and continuously transforms itself".

4.E-6 Investors in People (IIP): A UK-based award which specifies standards for the continuing development of employees.

4.E-7 Benchmarking for employee effectiveness: Learning from the best practice of companies leading in terms of employee development.

APPENDIX D

PANEL REVIEW SESSION RELATED DOCUMENTS

Panel Review Member (code): ___________ Panel Review: Case Study Beta				RT-1: No loading by resource (workstation) for a given product line RT-2: No Market/Operations plan on business value of rapid lead time capability	
Bolden's Modified Taxonomy (PST)				RT-3: Lead time is not seen as a function of the waste in the process	
Problem Domain	**Strategic Emphasis**	**Reference Number**	**"Best Practice"**	**Multi-vote (100 pts)**	**Pick "8"**
Design and Production	Improved Quality	1.A-1	Quality Standards		
		1.A-2	SPC		
		1.A-3	TPM		
		1.A-4	QFD		
		1.A-5	Poke-Yoke		
Inventory and Stock		2.A-1	Supply Chain Partnering		
		2.A-2	Customer Feedback		
		2.A-3	Conformance Checks		
Work Organization		3.A-1	Quality improvement teams		
		3.A-2	Operator responsibility		
		3.A-3	Quality feedback to operators		
		3.A-4	Quality training		
		3.A-5	Ergonomic design		
Wider Organization		4.A-1	Total quality management		
		4.A-2	Quality awards		
		4.A-3	Internationally Competitive Benchmarking for Quality		
Design and Production	Reduced Cost	1.B-1	Reduced WIP		
		1.B-2	JIT Production		
		1.B-3	Process Mapping		
		1.B-4	Design for Manufacturability		
		1.B-5	Re-usability		
		1.B-6	Value Engineering		
Inventory and Stock		2.B-1	Reduced Inventory		
		2.B-2	Single Sourcing		
		2.B-3	JIT Inventory Control		
		2.B-4	Forecasting		
		2.B-5	Logistics Management		
Work Organization		3.B-1	Downsizing		
		3.B-2	De-layering		
		3.B-3	Outsourcing		
		3.B-4	Flexible Labor Force		
Wider Organization		4.B-1	Lean production		
		4.B-2	Cost management		
		4.B-3	Financial performance		
		4.B-4	Time based management		
		4.B-5	Benchmarking: costs		
		4.B-6	Balanced Scorecard		
		4.B-7	Link Mfging to Strategy		

Case Gamma

Panel Review Member (code): _______

Panel Review of Field Recommendations	Relevance	Effectiveness	Implement ability	Overall Score	Notes
	"The recommendations are targeted at elimination of the root causes."	*"The recommendation, if implemented, would have a substantially positive impact on the manufacturing enterprise."*	*"The recommendation is practical and implementable without spending excessive time and resources."*		
	Please rate each recommendation on the folowing scale *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	*Please rate each recommendation on the folowing scale* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	*Please rate each recommendation on the folowing scale* Score 1: Strongly Disagree Score 5: Strongly Agree		
Recommendation #1: Establish a visual management program on the floor so that non-preferred conditions/methods are rapidly detected and corrected and preferred conditions/methods are clearly illustrated. This includes the use of such tools as 5S, one-point lessons, and "andon" indicators at the workstation to indicate current performance status in terms of both quality and throughput [e.g., red – immediate attention, yellow-danger, green-proceed]. Establish regular audit program to ensure compliance and effectiveness. Publicly track audit results so that					
Recommendation #2: Accelerate transition away from functional layout toward a cellular layout in order to enhance communications between processes. Continue to apply DOE and other statistical tools to shed light on the effect of processes (e.g., milling) on downstream processes (e.g., polishing). Regularly review capability of the measurement system in terms of repeatability and reproducibility.					
Recommendation #3: Develop a technical career path which encourages those that attained a high level of mastery to share, mentor, and develop others. This provides a career growth opportunity outside of management in terms of their mentoring other employees in developing greater skills. Establish "stair step" milestones so that employees can achieve intermediate levels of success. Consider classifying employees in terms of their ability to handle jobs of low-medium-high levels of difficulty and in terms of their skills at performing set-ups and process					

Panel Review of Field Recommendations	Relevance	Effectiveness	Implement ability	Overall Score	Notes
	"The recommendations are targeted at elimination of the root causes."	*"The recommendation, if implemented, would have a substantially positive impact on the manufacturing enterprise."*	*"The recommendation is practical and implementable without spending excessive time and resources."*		
	Please rate each recommendation on the folowing scale *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	*Please rate each recommendation on the folowing scale* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	*Please rate each recommendation on the folowing scale* Score 1: Strongly Disagree Score 5: Strongly Agree		
Recommendation #1: Develop ability to compare requirements with the capacity of key workstations. This will enable the constraint to be identified and appropriate operational measures to be tracked. This should guide improvement actions for increasing system capacity.					
Recommendation #2: Develop an overall business plan for establishing the value of rapid lead-time capability. This includes exploring partnerships with suppliers of key raw materials, reorganizing production operations to facilitate flow, finding ways of streamlining pre-production operations, and rationalizing appropriate capital investments. Of particular promise are ways to reduce design complexity (e.g., parametric CAD).					
Recommendation #3: Develop a value stream map both "as is" and "to be" for lead-time sensitive products. The "as is" case illustrates the waste involved in the total process. This should include the key activities (i.e., receipt, design, purchase, and fabricate), and the calculation of percent "value add" time for comparison against world class performance. The "to be" case establishes the vision for substantial process improvement. The mapping and transition effort should include a broad cross section of team					

Panel Review: **Member Background**

Name: ______________________________________

Panel Member (code) ______________
(linkage between name and code will remain confidential)

Items on this form (with the exception of the linkage between name and member code) are things things that you do not mind appearing in published research.

I. Academic Background (please list all degrees and institutions)

II. Approximate number of years working in manufacturing?

III. Selected Management and Executive positions held during career

IV. Current Position & Company (optional)

V. Professional Certifications Held
(e.g., Registered Professional Engineer, Six Sigma Black Belt, …)

VI. Exposure to Continuous Improvement Paradigms
Please rate on a scale of 1 (little) to 5 (extensive) the exposure you have had to the following areas

Areas	Score
Lean (Toyota Production System)	
Six Sigma	
Total Quality Management	
Theory of Constraints	
Other:	

VII. Enterprise Wide Exposure
Please rate on a scale of 1 (little) to 5 (extensive) the exposure you have had to the following areas

Areas	Score
Manufacturing	
Engineering & Design	
Human Resources	
Finance	
Quality	
Customer Service	
Sales & Marketing	
Continuous Improvement	
Information Systems	

VIII. Brief highlight of successful improvement/transformation that you have led?
(e.g., led lean transformation across multiple plants, doubled profits within 2 years, …)

1.
2.

Panel Review Member: **Session Feedback**

Name: ______________________________________

Panel Member (code) _____________
(linkage between name and code will remain confidential)

Please fill out the following information ….

1. How effective was the case study documentation in terms of providing you with sufficient information upon which to perform the reviews?
Please rate on a scale of 1 (insufficient) to 5 (sufficient)

	Rating
Case Alpha	
Case Beta	
Case Gamma	

2. How well did the survey instrument based on the Manufacturing Enterprise Taxonomy (MET) capture needed information?
Please rate on a scale of 1 (insufficient) to 5 (sufficient)

	Rating
Case Alpha	
Case Beta	
Case Gamma	

Was something missing, if so what?

3. How effective did the current reality tree (CRT) appear to be in terms of depicting the core problems facing the client?
Please rate on a scale of 1 (insufficient) to 5 (sufficient)

	Rating
Case Alpha	
Case Beta	
Case Gamma	

4. How well did Bolden's modified taxonomy define and organize the set of best practices for purposes of this research?
Please rate on a scale of 1 (insufficient) to 5 (sufficient)

	Rating
Case Alpha	
Case Beta	
Case Gamma	

5. What are the perceived <u>strengths</u> of this methodology, in terms of attacking the research problem of providing unbiased assessments to small and medium size manufactures?

6. What are the perceived <u>weaknesses</u> of this methodology, in terms of attacking the research problem of providing unbiased assessments to small and medium size manufactures?

APPENDIX E

IRB PROPOSAL AND RELATED DOCUMENTS

Mississippi State UNIVERSITY

April 9, 2007

Clayton Walden
153 Mississippi Parkway
Canton , MS 39046

RE: IRB Study #07-068: Taxonomy Based Assessment Methodology for Small and Medium Size Manufacturers

Dear Mr. Walden:

The above referenced project was reviewed and approved via expedited review for a period of 4/9/2007 through 3/15/2008 in accordance with 45 CFR 46.110 #7. Please note the expiration date for approval of this project is 3/15/2008. If additional time is needed to complete the project, you will need to submit a Continuing Review Request form 30 days prior to the date of expiration. Any modifications made to this project must be submitted for approval prior to implementation. Forms for both Continuing Review and Modifications are located on our website at http://www.msstate.edu/dept/compliance.

Any failure to adhere to the approved protocol could result in suspension or termination of your project. Please note that the IRB reserves the right, at anytime, to observe you and any associated researchers as they conduct the project and audit research records associated with this project.

Please refer to your docket number (#07-068) when contacting our office regarding this project.

We wish you the very best of luck in your research and look forward to working with you again. If you have questions or concerns, please contact me at cwilliams@research.msstate.edu or by phone at 662-325-5220.

Sincerely,

Christine Williams
IRB Compliance Administrator

cc: Allen Greenwood

Office for Regulatory Compliance
P. O. Box 6223 • 8A Morgan Street • Mailstop 9563 • Mississippi State, MS 39762 • (662) 325-3294 • FAX (662) 325-8776

INVESTIGATOR'S ASSURANCE
Mississippi State University
Institutional Review Board

Project Title: Taxonomy Based Assessment for Small and Medium Size Manufacturers

As Primary Investigator, I have ultimate responsibility for the performance of this study, the protection of the rights and welfare of the human subjects, and strict adherence by all co-investigators and research personnel to all Institutional Review Board (IRB) requirements, federal regulations, and state statutes for human subjects research. I hereby assure the following:

The information provided in this application is accurate to the best of my knowledge.

All named individuals on this project have been given a copy of the protocol and have acknowledged an understanding of the procedures outlined in the application.

All experiments and procedures involving human subjects will be performed under my supervision or that of another qualified professional listed on this protocol.

I understand that, should I use the project described in this application as a basis for a proposal for funding (either intramural or extramural), it is my responsibility to ensure that the description of human subjects use in the funding proposal(s) is identical in principle to that contained in this application. I will submit modifications and/or changes to the IRB as necessary to ensure these are identical.

I and all the co-investigators and research personnel in this study agree to comply with all applicable requirements for the protection of human subjects in research including, but not limited to, the following:

- Obtaining the legally effective informed consent of all human subjects or their legally authorized representatives, and using only the currently approved, consent form (if applicable); and
- Making no changes to the approved protocol or consent form without first having submitted those changes for review and approval by the Institutional Review Board; and
- Reporting serious and unexpected adverse effects to IRB Administration verbally within 48 hours and in writing within 10 days of occurrence, and all other unexpected adverse events in writing within 10 days of occurrence; and
- Promptly providing the IRB with any information requested relative to the project; and
- Promptly and completely complying with an IRB decision to suspend or withdraw its approval for the project; and
- Obtaining continuing review prior to the date approval for this study expires. I understand if I fail to apply for continuing review, approval for the study will automatically expire, and study activity must cease until IRB current approval is obtained.
- Your study and any associated records may be audited by the IRB to ensure compliance with the approved protocol.

Name of Primary Investigator / Researcher: Clayton T. Walden

Signature: Clayton T. Walden

I assume responsibility for ensuring the competence, integrity and ethical conduct of the investigator(s) for this research project. The investigator(s) is/are fully competent to accomplish the goals and techniques stated in the attached proposal. Further, I certify that I have thoroughly reviewed this application for readability and accuracy and the study is clearly described herein.

Name of Advisor: Dr. Allen Greenwood

Signature:

THE MISSISSIPPI STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD

FOR THE PROTECTION OF HUMAN SUBJECTS IN RESEARCH

Protocol Submission Form

PRINCIPAL INVESTIGATOR / RESEARCHER INFORMATION

Name: Mr. Clayton T. Walden

MSU Net ID: ctw29

Daytime Phone Number: (601) 407-2713

Mailing Address: 153 Mississippi Parkway, Canton, MS. 39046

City/State/Zip: Canton, MS. 39046

E-Mail Address: walden@cavs.msstate.edu

Department: Center for Advanced Vehicular Systems

IRB and Human Subjects Protections Education completed on 1/13/07

FACULTY ADVISOR

Advisor: Dr. Allen Greenwood

MSU Net ID: agg4

Daytime Phone Number: (662) 325-7216

Advisor's E-Mail Address: greenwood@ise.msstate.edu

Department: Industrial and Systems Engineering

Campus Mail Stop: 9542

IRB and Human Subjects Protections Education completed on 02/25/07

ADDITIONAL INVESTIGATORS / RESEARCHERS

Steve Puryear, (601) 407-2739, 153 Mississippi Parkway, Canton, MS 39046, spuryear@cavs.msstate.edu, IRB and Human Subjects Education completed on 8/22/05.

Lucas Simmons, lmsS47, (601) 407-2741, 153 Mississippi Parkway, Canton, MS 39046, lsimmons@cavs.msstate.edu, IRB and Human Subjects Education completed on 2/19/07.

Travis Hill, twh2, (601) 407-2734, 153 Mississippi Parkway, Canton, MS 39046, thill@cavs.msstate.edu, IRB and Human Subjects Education completed on 2/22/07.

Robert Sheely, ras193, (601) 407-2714, 153 Mississippi Parkway, Canton, MS 39046, rsheely@cavs.msstate.edu, IRB and Human Subjects Education completed on 2/21/07.

TITLE of project:

Taxonomy Based Assessment Methodology for Small and Medium Size Manufacturers

Is this an original submission or a revision? Original

If this is a revised application, please list the docket number assigned to the first submission of the study.

PROJECT PERIOD: from _Upon IRB Approval__ to _12/31/07

STUDY FUNDING

Provide information about how the study costs will be supported

_X___Department funds ____Personal Funds ____No cost study

____Other, specify:

____External Funding

Agency:

SPA Proposal or Fund/Account Number: 250604

PI of Award (if different than Principal Investigator/Researcher listed above):

PROPOSED PROTOCOL:

TAXONOMY BASED ASSESSMENT OF SMALL AND MEDIUM SIZE MANUFACTURERS

I. Personnel and Qualifications

Person: Clayton T. Walden

Role: Principal Investigator

Experience: BS and MS in Industrial Engineering from Mississippi State University. Walden is a certified Jonah from the Goldratt Institute. Walden has several years of work experience including; 12 years experience working as engineer and manager within manufacturing companies, 3 years of teaching undergraduate courses within industrial engineering, 3 years as manager of engineering extension at CAVS Extension.

Training on Procedure/Technique: Walden is the developer of the methodology that is being piloted. He has performed numerous supplier quality assessment as an engineer/manager within private industry. Also, Walden as performed numerous manufacturing assessments through involvement within Mississippi's Manufacturing Extension Partnership (MEP).

Periodic Review of skills/abilities: Faculty mentor will provide guidance and advice prior to each case study.

Person: Dr. Allen Greenwood

Role: Dissertation Advisor

Experience: Dr. Greenwood is a Professor of Industrial Engineering within the Department of Industrial and Systems Engineering Department at Mississippi State University. He is co-director of the Management Systems Engineering Laboratory. Dr. Greenwood has nine years of industrial experience. In addition he has co-authored numerous papers in such peer reviewed journals as IEEE Transactions on Reliability, European Journal of Operations Research, Naval Research Logistics among others.

Training on Procedure/Technique: Dr. Greenwood has guided the development of the assessment tool dissertation advisor to the project's principal investigator.

Periodic Review of skills/abilities: Maintains on-going IRB certification.

Other people that form the pool of assessors from which this research project will draw upon are listed as follows. The assessment methodology recommends in addition to the lead assessor, at least one additional co-assessor will be included. For the piloting of the methodology, the lead assessor will be the project principal investigator. The selection of co-assessors will be based upon schedules and anticipated workload.

<u>Potential Set of Qualified Co-Assessors</u>

Person: Steve Puryear

Role: Assist in the pilot assessments using the proposed methodology

Experience: 25 years experience as an manager/CFO within both the manufacturing and transportation industries. Puryear has BS in Accounting and MBA from Mississippi College.

Training on Procedure/Technique: Puryear will receive training on the specific methodology developed from this research by the lead researcher. He received training in specific methodology delivered by lead researcher on 02/22/07.

Periodic Review of skills/abilities: Assessment methodology will be reviewed immediately prior to conducting the case study. This review will take place by the lead researcher.

Person: Travis Hill

Role: Assist in the pilot assessments using the proposed methodology

Experience: Hill has a BS and MS in Industrial Engineering from Mississippi State University. Hill has three years experience as an engineer performing projects which support private industry. Currently serves as a field engineer at CAVS Extension in Canton, MS.

Training on Procedure/Technique: Hill received training in specific methodology delivered by lead researcher on 02/22/07.

Periodic Review of skills/abilities: Assessment methodology will be reviewed immediately prior to conducting the case study. This review will take place by the lead researcher.

Person: Lucas Simmons

Role: Assist in the pilot assessments using the proposed methodology

Experience: Simmons has a BS in Mechanical Engineering from Mississippi State University. He has four years experience as an engineer/manager within private industry. Currently serves as a field engineer at CAVS Extension in Canton, MS.

Training on Procedure/Technique: Simmons will receive training on the specific methodology developed from this research by the lead researcher. Simmons received training in specific methodology delivered by lead researcher on 02/22/07.

Periodic Review of skills/abilities: Assessment methodology will be reviewed immediately prior to conducting the case study. This review will take place by the lead researcher.

Person: Robert Sheely

Role: Assist in the pilot assessments using the proposed methodology

Experience: 30 years experience as an engineer/manager within the Information Technology industry. Currently serves as Manager of Information Technology and Business Systems at CAVS Extension in Canton, MS.

Training on Procedure/Technique: Sheely has received training in specific methodology delivered by lead researcher on 02/22/07.

Periodic Review of skills/abilities: Assessment methodology will be reviewed immediately prior to conducting the case study. This review will take place by the lead researcher.

II. Research Protocol

1. Site of Work

Case studies will be conducted at the site of three or more small to medium size manufacturers (i.e., less than 500 employees). These sites have not been selected yet. However, it is anticipated that these three sites will be located within the state of Mississippi. The identification of the actual site for the case study depends upon the development and approval of recruitment materials and consent forms. Case study documentation, panel review session, and analysis of results will all be conducted at the CAVS extension facility in Canton, MS.

2. General Purpose of the Project

The development of a taxonomy based assessment methodology for use within small to medium size manufacturers. This methodology will be piloted with manufacturers using a case study approach. The case studies will be presented to a panel of manufacturing experts, whose responses will be documented and analyzed.

3. Benefits may result from the study that would justify asking the subjects to participate?

The development of a more objective means for assessing small to medium size manufacturers assists in addressing one of the recognized barriers to increasing the performance of smaller manufacturers. This need was first identified by the National Research Council's 1993 report and re-confirmed with a more recent Department of Commerce report. The companies participating in the case study receive the benefit of this new assessment methodology, through access to assessment based recommendations. The panel review participants are provided the opportunity to add to their experiences by reviewing the prepared cases and considering the problem of logically selecting from a broad set of possible prescriptions based upon case study data.

4. Details of Procedures that relate to subject's participation

There are two types of subjects defined within this proposed research. The first type refers to those people who are employed at the site of the manufacturer where the assessment is piloted. The second type refers to those who are invited and elect to participate in the review panel of the previously documented case study.

Case Study Participants:

For each participating manufacturing firm, a senior management representative (SMR) will be designated. This person will receive the initial document describing the assessment research and the request to participate in the assessment as part of this research project.

Prior to Assessment: The leader researcher will meet with the SMR in order to determine whether or not the firm is a candidate for the research pilot. In addition to the firm's willingness to serve as a pilot location the following conditions are required.

- Agree to allow the assessment team access to key personnel during the one to two day on-site assessment.
- An agreement which ensures the voluntary cooperation of key employees in the assessment. This is essential to the ethical conduct of this research. If one of the firm's employees determines not to cooperate, then this will not result in any negative consequences towards that individual.
- Agree to let the researcher publish the case study as part of a doctoral dissertation. The company name will not be used but will be referenced through a pseudo-name.
- Acknowledgement that the review of individual employee performance is beyond the scope of the assessment.

If the firm agrees to the above conditions, an initial survey instrument will be sent prior to the assessment visit. The SMR will use the instrument to perform an initial review. This prepares the company for the type of questions and discussions that will be required in order to participate effectively in the pilot.

During Assessment: Once the assessment team is on-site, the assessment will begin with an opening meeting with the SMR and the key employees. Each person will be briefly instructed of the potential risks and benefits of participation as outlined on the informed consent document. The subjects will be asked if there are any questions and an opportunity will be provided to each subject to sign the informed consent document. It is anticipated that the opening session will last approximately one hour. It is expected that individual one-on-one sessions will follow. A plant tour in order to provide the assessment team with a first hand account of the firm's operations. The assessment will conclude with an ending group session, which includes all the key employees. The assessors will confirm the firm's fit within the manufacturing enterprise taxonomy (MET). Also, the final validation of the current realty tree (CRT) will be conducted via interaction between at least the lead assessor and the SMR. Also, the initial set of recommendations will be provided to the SMR in order to provide an opportunity for feedback. The final recommendations will be given to the SMR by the lead assessor.

Post Assessment: The documented case study using pseudo names will be provided to the SMR. The documentation packet will include the fit within the MET, applicable current reality trees, and a set of recommendations. The SMR will be asked to rate their receptivity to the recommendations.

Review Panel Participants:

A review panel will be established, which includes at least five reviewers (i.e., case study appraisers). As part of the selection process these reviewers will be asked to submit their resume and qualifications will be established based upon the resume. Panel review members must meet the following conditions.

- At least 10 years of experience in successfully leading small to medium size manufacturing firms.
- Expertise in leading manufacturing improvement paradigms including lean manufacturing, theory of constraints, factory physics, and Six Sigma.
- Willingness to denote their time to case study review.
- No current association with any of the case study firms.

While Panel participants will not be paid for their time, it is reasonable for out of town participants to have reasonable travel expenses covered. The Director of CAVS Extension will approve the travel as necessary. The review panel meeting will be structured so that it will last between 4 and 6 hours. It is possible that more then one panel review meeting will take place due to possible scheduling conflicts of panel members.

Pre-Panel Interactions: The introductory materials will include the purpose of the panel, the duration, and an informed consent form. The consent form will include such items as any potential risks in participation, voluntary nature of participation, absence of any negative reaction from the university should they at any time feel like they should withdraw from participation. The lead researcher will discuss the informed consent document prior to the review meeting. Prior to participation in the review meeting, the lead researcher will collect the signed informed consent document.

<u>During Panel Interactions:</u> The project PI will provide each with all three of the documented case studies: including the evaluation and diagnosis sections. Also each panel member will receive a copy of the production systems taxonomy (PST) of possible prescriptions. The panel members will be asked to rate the association of each element of the PST with respect to each of the root causes. A final selection will made of a fixed number of prescriptions after the initial rating has been completed. A facilitated group discussion among panel members will be lead by the lead researcher.

<u>Post Panel Interactions:</u> None.

5. List all vulnerable subject populations to be included and additional precautions being taken to ensure their protection.

Because of the nature of this case study research, subjects will typically be professionals working within an SME. Therefore, it is highly unlikely that these subjects would include such vulnerable populations as minors, students, prisoners, adults with cognitive impairments, and non-english speaking people. However, those individuals employed at the SME and who participate in the assessment has been identified as a vulnerable population. The assessment methodology focuses on the opportunities facing the firm from an overall systems perspective. The assessment methodology piloted is not intended to serve as a means of evaluating individual employee performance. This is clearly indicated in the recruiting materials provided to the SMR before the pilot is conducted. While issues of individual performance are not the focus of this research, it remains possible that issues related to employee performance may arise during the assessment process.

The following defines potential risks and precautions taken to mitigate risks to employees which voluntarily choose to be involved in the assessment.

Risk 1: A negative consequence could result against an individual participating in the case study if the client's management team makes inferences from the assessment regarding lack of job performance.

Countermeasure 1.1: In the recruiting materials it will be very clearly communicated that the 1-2 day on-site assessment is focused on systemic issues only. The evaluation of a particular employee's job performance is not within the scope of the assessment. Ultimate determination of employee performance and appropriate HR action is outside the scope of the 1-2 day enterprise wide assessment.

Countermeasure 1.2: If at any time during the on-site assessment an employee believes that he or she is threatened, then they have the right to not answer any question. The consent form, signed by the SMR will indicate that the SME agrees to the requirement of this research protocol that participation of employees is voluntary. This will clearly indicate that if an employee withdraws from participation, the employee will not receive any negative consequences from the SME.

Countermeasure 1.3: One-on-one conversations between the assessors and employees will be documented based upon role and not by the individual's name. Also, the employee consent form will indicate the purposes of such conversations with assessor (whether one-on-one or group) is the conduct of the assessment. Therefore, the content and responses, while not including individual names, may need to be referenced by researchers and others at the SME as part of the assessment process.

Countermeasure 1.4: Additional precautions will be that names of employees, beyond the senior management representative will not be included in any of the project documentation provided to the client. Employee feedback will be noted and labeled by role and position, a separate cross index will be kept in a separate file folder.

Risk 2: Recommendations derived from the assessment the manufacturing enterprise implements measures may result in unintended negative consequences with respect to enterprise performance. This condition could result in negative career consequences to many employed at the SME. Of course, this event could occur from a variety of possible causes, such as faulty and incomplete methodology, lack of honest feedback from participants. Of course, many factors unrelated to the assessment may occur. However, the level of this risk is no higher than the normal risks that exist for employees engaged within manufacturing at small to medium size manufacturing firms (i.e., SMEs).

Counter Measure 2.1: The recruiting material and the consent forms signed by the subjects will document that the firm being assessed assumes all responsibility for any actions which may be directly or indirectly associated with case study. The purpose of the assessment is to develop recommendations for the SME to consider implementing. Issues of implementation are not the responsibility of this research.

6. How will subjects be selected and recruited?

Case Study Participants: The subjects are invited to participate in this research by virtue of the firm's agreeing to in the case study. The selection criterion of the firm involvement in the pilot is as outlined below.

- The company must be a manufacturer with less than 500 employees on site (i.e., Department of Commerce's definition for a small to medium size manufacturing enterprise - SME).
- The company's SMR must be willing to agree to the conditions of the assessment. This includes the assumption of transparency and honesty during the conduct of the assessment. Transparency means that no line of reasonable inquiry is outside the bounds of the assessors and that responses are voluntary (i.e., unforced).
- The SMR agrees that if any of the employees become uncomfortable with the assessment they are free to withdraw. If any at any point the employee decides to no longer participate in the pilot, then the company will not take any negative action against the employee.

Review Panel Members: Selected based upon at least 10 years of experience of operations and/or engineering experience leading continuous improvement within a manufacturing firm.

7. What inducements will be offered?

None for the case study participants. However, participants in the panel review may receive re-imbursement for out of town travel expenses.

8. How many subjects will be used? List any salient characteristics of subjects (e.g., age range, sex, institutional affiliation, …)?

Since the actual number of subjects interviewed as part of the assessment depends upon the size and the complexity of the company participating in the case study, the exact number of subjects is not known. However, it is possible to estimate a range which the actual number of subjects will fall within. Also, the subject's features (e.g., ethnicity, sex, age, weight, citizenship, …) are simply not relevant to this research.

Case Study Participants:

The actual number of employees interviewed during the assessment will vary based upon the size and complexity of the firm undergoing the assessment. It is expected that most assessments will typically include interviews of 4 or more people and typically no more than 10 people on-site. Since there is expected to be three case studies, the total number of participants will lie between 12 and 40.

The actual people for interaction within the assessment methodology will be a function of the type of people within each of the critical areas of responsibility within the firm. These are primarily manufacturing and business professionals. It is anticipated that these people will posses various levels of post secondary education, many with college degrees.

Panel Review Members:

The minimum number of review panel members will be 5. These members will be invited based upon a minimum of 10 years of manufacturing experience across a variety of types of industries. Also, these people will have had responsibilities which have included operations and continuous improvement programs. Members of the review panel should have high levels of knowledge regarding popular business transformation strategies such as total quality management (TQM), Six Sigma, and lean manufacturing.

9. Number of times researchers will interact with each subject?

Case Study Participants: The lead assessor will have several interactions (i.e., at least three) with the SMR. This includes up front discussion (including all pertinent issues of informed consent and procedures regarding confidentiality and privacy protections) and commitment to perform the assessment. Continual contact will occur with the SMR during the period of on-site assessment. Follow-up validation with the SMR will occur after the on-site phase is completed. This includes validation of the firm's fit with in the MET, CRT, and presentation of recommendations.

Interactions with other employees within the firm will be considerably less than the SMR. These people will typically be interviewed up to two times (once individually and once collectively) during the 1-2 day on-site assessment period.

Panel Review Members: Interactions will occur during the recruiting process and will culminate in a one day panel review session. The review session will include a presentation of the case, explanation of the firm's fit within the MET, an overview of the PST, and instructions regarding responses. Also a facilitated discussion will be conducted between the reviewers and the lead researchers.

10. What will the subjects do, or what will be done to them, in the study?

Case Study Participants: Questions will be asked based upon the MET based survey instrument. Follow-up non-scripted questions will be asked to probe futher for clarity and linkages. Also questions will be asked regarding “undesirable effects” that the firm currently faces. As appropriate, these subjects will be asked to rate and/or prioritize issues and problems so that a pattern emerges across functions within the organization.

Additional responses will be required from the SMR regarding validation of the fit within the MET, validity of CRT, and opportunity for feedback regarding recommendations.

See attached assessment survey instrument for the basic questions which will be asked and comprises the overall assessment. The actual number of questions asked to each subject will depend upon their role. Generally the questions will be asked within an open and general discussion. Also the assessors may need to ask additional probing questions either within a group or individual setting. These unscripted questions will fall within the domain established by the formal survey instrument in order and their purpose may be to clarify earlier responses or to better understand causative linkages.

The SMR will be asked to rate their receptivity to the recommendations.

Panel Review Members: The purpose of the panel review is to provide feedback relative to the case studies. The case studies will be presented by the lead researcher and each panel review member will be asked to rate each element of the PST relative to its association with the root cause identified in the diagnosis phase of the assessment. Also, each participant will be asked to select a subset of the PST that will be used to form the basis of that participant’s recommendation. The ratings and selection provided by each panel member will be used for analysis regarding the reliability and validity of the piloted methodology. The analysis will include the level of consistency across the panel review members as well as the level of agreement relative to the assessment team.

11. How do you intend to obtain the subjects' consent?

Case Study Participants: SMR informed consent form will be filled out prior to their participation in the case study. In addition, this form will reference the signature of the SMR ensuring their approval that employee involvement in the case study is strictly voluntary. This includes the right of the employee to not answer, withdraw from participation if at any point they become uncomfortable with continuing. This includes the assurance that no negative consequence will result to the employee stemming from either their cooperation or non-cooperation.

See attached copy of the informed consent forms for both the SMR and company employees.

Panel Review Members: Panel members will sign informed consent forms prior to participation in the case review. See attached copy.

12. Assessment of risk?

This research involves no elements of deception, and no physical risks beyond those associated within the subjects typical work environment. The potential risk involving the only vulnerable population – employees has already been discussed and counter measures presented.

Another element of risk involves the overall effectiveness of the assessment from the perspective of the on-going health of the firm. It is possible that increased risk of negative consequences could result to all employees at the assessed firm. However it is clearly communicated in the recruitment materials as well as the SMR's informed consent that this is a pilot of a methodology from emerging research. The primary purpose of the pilot is to test the effectiveness of the methodology. The research will document lessons learned, which through further research efforts (outside the present scope) target the development of a methodology ready for "production use."

13. How do you ensure confidentiality of information collected?

Case Study Participants: All comments from individuals will be with respect to position and specific names will not be used. A project cross reference index, which will be maintained separately from other research materials, will indicate the actual name of the company and the senior management representative. This file and all signed consent forms will be stored at CAVS Extension in Canton, MS. After the project has been completed the cross referenced file, will be stored at a separate location (dissertation advisor's personal files at 260 McCain Engineering building on campus).

Participating firms will be referenced by pseudo names in the formal development of the case study.

Panel Review Participants: There is minimum risk associated with being a member of the review panel. Each panel member will be cited within an appendix of the dissertation, including their backgrounds and qualifications to serve on the panel. However, to minimize whatever small risk facing these members their individual responses will be coded. A cross reference between coding and participant names will be kept in a separate file location and stored after the close of the project with the dissertation advisor's personal files (260 McCain Engineering Building on campus).

14. Are approvals needed from another MSU regulatory committee?

None

Consent Form: Subjects Participating in Case Study

Title of Study: Taxonomy Based Assessment Methodology for Small and Medium Size Manufacturers.

Researcher(s) and University Affiliation: Clay Walden, Mississippi State University, Center for Advanced Vehicular Systems Extension.

- **What is the purpose of this research project?**

The purpose of this project is to develop and pilot an assessment methodology focused on addressing the needs of small to medium size manufacturers.

- **How will the research be conducted?**

The research includes a piloting of the assessment methodology. Your company has been contacted and agreed to serve as a case study for the pilot of this methodology. The assessment includes a one to two day on-site review, the resulting recommendations will be shared with the company's senior management representative. Documented case studies will be presented to a Review Panel for feedback.

- **What is my responsibility as a participant**

Please provide open and honest feedback regarding any of the survey questions and follow-up probing questions.

- **Are there any risks or discomforts to me because of my participation?**

The assessment deals with the development of recommendations targeting improved manufacturing performance. These recommendations require changes from current operations. If the company chooses to implement some of these recommendations, there are risks inherit in any change. However, this research posses no more risk than is typical within the dynamic nature of any small to medium size manufacturer. It should be noted that maintaining the status quo carries with it inherent risk.

- **Does participation in this research provide any benefit to others or to myself?**

This project provides long term benefits to small and medium size manufacturers by providing a more objective basis for conducting manufacturing assessments.

- **Will this information be kept confidential?**

One-on-one conversations with the assessors will be noted and documented as part of the assessment process. However, the names of individuals will not be used in the official project documentation. Companies will be referenced within each case study by a pseudo name. Also panel review members will not be referenced in the official project documentation by their names.

- **Who do I contact with research questions?**

The lead researcher is Clay Walden, (601) 407-2713, walden@cavs.msstate.edu, Manager of Engineering Extension, Center for Advanced Vehicular Systems, Mississippi State University. If you have additional questions concerning your rights as a subject, please contact the MSU Regulatory Compliance Office at 662-325-3294.

- **What if I do not want to participate**?

Participation in the case study is strictly voluntary and if at any time you feel uncomfortable to answer a question then you are under no obligation to answer that question. The senior on-site management has agreed that there will be no negative consequences to you as an employee as a result of either your participation or non-participation in the case study (reference attached consent form of the company's Senior Management Representative).

Two signed copies of this form will be generated: one for the subject and one for the researcher.

___________________________ ________________

Participant Signature Date

___________________________ _____________

Investigator Signature Date

Consent Form: Subjects Participating in Review Panel

Title of Study: Taxonomy Based Assessment Methodology for Small and Medium Size Manufacturers.

Researcher(s) and University Affiliation: Clay Walden, Mississippi State University, Center for Advanced Vehicular Systems Extension.

- **What is the purpose of this research project?**

The purpose of this project is to develop and pilot an assessment methodology focused on addressing the needs of small to medium size manufacturers.

- **How will the research be conducted?**

The research includes a piloting of the assessment methodology. A set of companies has agreed to serve as case studies for the pilot of this assessment methodology. The assessment includes a one to two day on-site review, and the resulting recommendations are shared with the company's senior management. Documented case studies will be presented to a Review Panel for feedback in order to provide a measure a reliability and validity.

- **What is my responsibility as a participant**

Please provide open and honest feedback regarding the appraisal of case studies.

- **Are there any risks or discomforts to me because of my participation?**

For a member of the panel review, the risks are minimal. However, panel review members will be asked to make judgments about case studies in which information about the company is limited. This could cause anxiety due to the need to make decisions in which there is often no clear cut answer.

- **Does participation in this research provide any benefit to others or to myself?**

This project provides long term benefits to small and medium size manufacturers by providing a more objective basis for conducting manufacturing assessments. Each panel member will be cited within an appendix of the dissertation, including their backgrounds and qualifications to serve on the panel.

- **Will this information be kept confidential?**

However, to minimize whatever small risk facing panel members their individual responses will be coded. Names of individuals will not be used in the official project documentation.

- **Who do I contact with research questions?**

The lead researcher is Clay Walden, (601) 407-2713, walden@cavs.msstate.edu, Manager of Engineering Extension, Center for Advanced Vehicular Systems, Mississippi State University. If you have additional questions concerning your rights as a subject, please contact the MSU Regulatory Compliance Office at 662-325-3294.

- **What if I do not want to participate**?

Participation in the case study is strictly voluntary and if at any time you feel uncomfortable to answer a question then you are under no obligation to answer that question. The senior on-site management has agreed that there will be no negative consequences to you as an employee as a result of either your participation or non-participation in the case study (reference attached consent form of the company's Senior Management Representative).

Two signed copies of this form will be generated: one for the subject and one for the researcher.

__________________________ ________________

Participant Signature Date

__________________________ _____________

Investigator Signature Date

Consent Form: Subjects Serving As Senior Management Representative (SMR)

Title of Study: Taxonomy Based Assessment Methodology for Small and Medium Size Manufacturers.

Researcher(s) and University Affiliation: Clay Walden, Mississippi State University, Center for Advanced Vehicular Systems Extension.

- **What is the purpose of this research project?**

The purpose of this project is to develop and pilot an assessment methodology focused on addressing the needs of small to medium size manufacturers. The case study will focus primarily on the use of the prototyping of this methodology. The ultimate responsibility of the company's performance lies with the firm and it not the responsibility of this research.

- **How will the research be conducted?**

The research includes a piloting of the assessment methodology. Your company has been contacted and agreed to serve as a case study for the pilot of this methodology. The assessment includes a one to two day on-site review, the resulting recommendations will be shared with the company's senior management representative. Documented case studies will be presented to a Review Panel for feedback.

- **What is my responsibility as a senior management representative (SMR)?**

Allow voluntary cooperation of any employee which participates and that no negative consequence will result in harm as a result of the employee's participation or non-participation in the pilot assessment.

- **Are there any risks or discomforts to me because of my participation?**

The assessment deals with the development of recommendations targeting improved manufacturing performance. These recommendations require changes from current methods of operating. If the company chooses to implement some of these recommendations, there are risks inherit in any change. However, this research posses no more risk than is typical within the dynamic nature of any small to medium size manufacturer. It should be noted that the just maintaining the status quo carries with it inherent risk. Caution should be noted that this is a pilot of emerging research. Senior management bears the ultimate responsibility for its own performance; the firm may choose to implement some, none, or all its recommendations. The purpose of the case is to pilot the proposed assessment methodology so that feedback can be obtained.

- **Does participation in this research provide any benefit to others or to myself?**

This project provides long term benefits to small and medium size manufacturers by providing a more objective basis for conducting manufacturing assessments. If the piloting of the case study is successful there is the possibility that the assessment could provide beneficial to the company.

- **Will this information be kept confidential?**

Information obtained during the assessment, which is important to the case study, will be documented and published as appropriate to the case study. However, the company's names and names of individual participants will not be disclosed. Companies will be referenced within each case study by a pseudo name.

- **Who do I contact with research questions?**

The lead researcher is Clay Walden, (601) 407-2713, walden@cavs.msstate.edu, Manager of Engineering Extension, Center for Advanced Vehicular Systems, Mississippi State University. If you have additional questions concerning your rights as a subject, please contact the MSU Regulatory Compliance Office at 662-325-3294.

- **What if I do not want to participate**?

Participation in the case study is strictly voluntary and if at any time you feel uncomfortable to proceeding, then you and your organization has the right to withdraw.

Two signed copies of this form will be generated: one for the subject and one for the researcher.

___________________________ _______________

Participant Signature Date

___________________________ _____________

Investigator Signature Date

Taxonomy Based Manufacturing Assessment Methodology

Serving as a Pilot Site: Case Study Research

Recruitment Material

Introduction:

The purpose of this document is to provide your company with an overview of the expectations involved in participating as a pilot site for this research. This research is part of dissertation within Mississippi State University's Department of Industrial and Systems Engineering.

The research topic is the development of a taxonomy based assessment methodology for small to medium size manufacturers. The goal of the assessment is to generate a set of recommendations that the company consider implementing for the purpose of improved manufacturing performance. This is a company-wide assessment and the evaluation of individual employees is outside the scope of this endeavor.

This research is seeking to identify manufacturers willing to serve as pilot sites. *Caution should be noted that this is a pilot of emerging research. Senior management bears the ultimate responsibility for its own performance. The firm may choose to implement some, none, or all the recommendations resulting from the assessment.* The purpose of the pilot is to serve as the basis for further modifications and enhancement of the methodology which may reside outside the scope of this current effort. Each pilot of the assessment methodology will be documented as a case study and included in the publication of the dissertation.

In order to protect confidentiality and promote assessment impartiality, pseudo company names will be used in all published material.

Requirements:

1. The manufacturing site assessed must have less than 500 employees.
2. The company must identify a senior management representative (SMR) and be willing to allow the 1-2 day on-site assessment.

3. Any employees involved in the assessment must participate voluntarily and that no negative consequence will result from either their participation or non-participation in the assessment.
4. Research ethics require that each participant, prior to participating in the assessment, have an opportunity to review the informed consent document and voluntarily sign it.

Expectations:

1. The basic survey instrument will be sent to the SMR prior to the assessment and the company is asked to provide initial answers to these questions.
2. The conduct of the assessment including unscripted probing questions will be conducted in an open and honest atmosphere both on the part of the assessor and participants.
3. Individual names will not be found in the case study documentation. A labeling scheme will be developed which reflects the individual's role, without referring to specific job titles or proper names.
4. The deliverable of the assessment includes the documented case study and the set of recommendations. The site's senior management representative will be asked to rate their receptivity to the recommendations.
5. The case study, under the company's pseudo name, will be presented to a review panel. This review panel will provide input regarding the reliability of the assessment methodology.

For any additional questions, please contact Clay Walden, Center for Advanced Vehicular Systems Extension, Canton, MS., (601) 407-2713, walden@cavs.msstate.edu

Taxonomy Based Manufacturing Assessment Methodology

Serving as a Member of the Case Study Panel Review Board

Recruitment Material

Introduction:

The purpose of this document is to provide your company with an overview of the expectations involved in participating as a member of the Case Study Panel Review. This research is part of dissertation within Mississippi State University's Department of Industrial and Systems Engineering.

The research topic is the development of a taxonomy based assessment methodology for small to medium size manufacturers. The goal of the assessment is to generate a set of recommendations that the company consider implementing for the purpose of improved manufacturing performance. This research will pilot the assessment methodology with manufacturers that will result in documented case studies. These case studies will be documented and presented to a Review Panel, which will select recommendations based upon a taxonomy of previously defined prescriptions. The review panel provides an opportunity for the researcher to obtain external feedback regarding the reliability and validity of the assessment methodology.

In order to protect confidentiality and promote assessment impartiality, pseudo company names will be used in all published material.

Requirements:

1. The member of the Panel Review must have at least 10 years of experience in management of operations and/engineering including extensive experience in leading continuous improvement within a manufacturing firm. Expertise in leading manufacturing improvement paradigms including Lean, Six Sigma, Theory of Constraints, and Total Quality Management.
2. The review member must be willing to serve on a voluntary basis for the 4-6 hour review meeting.
3. Research ethics require that each member, prior to participating in the review, have an opportunity to review the informed consent document and voluntarily sign it.

Expectations:

1. Open and honest evaluations of the case study presented.

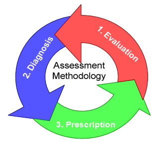
2. The names and affiliations of individual members will be documented in the published research.
3. The conduct of the assessment including unscripted probing questions will be conducted in an open and honest atmosphere both on the part of the assessor and participants.
4. Individual names will not be found in the case study documentation. A labeling scheme will be developed which reflects the individual's role, without referring to specific job titles or proper names.
5. The deliverable of the assessment includes the documented case study and the set of recommendations.
6. The case study, under the company's pseudo name, will be presented to a review panel. This review panel will provide input regarding the reliability of the assessment methodology.

For any additional questions, please contact Clay Walden, Center for Advanced Vehicular Systems Extension, Canton, MS., (601) 407-2713, walden@cavs.msstate.edu

APPENDIX F

CASE STUDIES

CAVS EXTENSION Center for Advanced Vehicular Systems — Mississippi State University



Case Study - Alpha:

Pilot of Taxonomy Based Assessment Methodology (TBAM)

Assessment Team:

Clay Walden, Robert Sheely, Travis Hill

May 15 – June 15, 2007

MEP ms Manufacturing Extension Partnership of Mississippi

1

Case Study: Alpha

Overview of "Alpha" Case Study

May 21-22, 2007

Assessors: Clay Walden, Robert Sheely, Travis Hill (Mississippi State University, CAVS Extension)

Scope: Focus primarily on the traditional business of embedded electronics which are the products that manufacturing is currently supporting. Other nontraditional business units were not included.

Client Participants

Manager of Operations

Manager of Process Engineering

VP of Marketing

Chief Technology Officer

Materials Manager

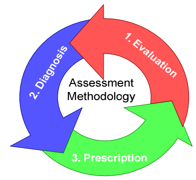
VP of Operations

Products: Embedded Electronics
Printed Circuit Boards (PCB)
Systems

Markets
Telecom
Military
Small Opportunities

Employees
160 employees
50 hourly
110 Professional and nonexempt

2



Evaluation Stage

Objective: Identify the client's fit within the Manufacturing Enterprise Taxonomy (MET) and identify Undesirable Effects (UDEs) using the MET based survey instrument.

General Observations

- Business is characterized by low volume high variety product mix. Products are increasingly complex due to rapid advancements in electronics and computing technologies.
- Several business strategies have been used recently, but not had the desired result. There was no strong evidence that current strategy is endorsed and supported by all members of the team.
- Market has become increasingly competitive within recent years, large players have moved from being primarily customers to becoming competitors stemming from in-sourcing and direct competition.
- Strong sense is that ability to respond rapidly to customer requests is valued by customers (fast from concept to prototype).
- Margins are "thin" upfront under the assumption that once the business is won (incumbent) then next rounds of orders will come with greater margins resulting. At times the subsequent orders have not materialized.
- Little evidence of sustained team based results - particular people are noted and recognized for getting results. In many cases data clearly points out the problem/opportunity, but follow through to root cause elimination is not routine. This is particularly a problem when problems cross functional boundaries.
- Successful problem solving has been associated with particular jobs, but across the board results have been relatively small and incremental.

General Observations (cont.)

- Plant layout and management is more functional than cellular. Opportunities exist for tighter integration of repair into product flow and improved discipline of open orders to eliminate "pooling."
- Plant lead-times are 8-10 days while total value add time is 6-8 hours - represents an opportunity to drastically reduce and become more robust to unexpected variation in customer delivery. A more compressed production cycle allows less time for interruptions to flow.
- Manufacturing task includes both support for proto-typing and production of mature products presents dramatically different requirements to manufacturing.
- Long changeovers (1 to 6 hours) on SMT is an obstacle to enhanced flexibility within manufacturing.
- Rapid turnaround requirements relative to ECO, changes, “mods”, and "spins" cause chaos within ongoing manufacturing.
- 1500 to 2000 active part numbers. 150-300 different components on a typical board.
- As component prices have dropped, the same labor content in terms of dollars has gone from less than 5% of product cost to 20-25%.
- Standard lead-times are quoted as 4-6 weeks.
- New Products, modifications of standard products (best), standard products (highest margins).

1.0 Business Environment

1.0 Business Environment *"descriptive"*		**Level 1**	***Score*** →	**Level 5**	***Evidences***
1.1 Competitive Environment	***1.1.1 Intensity of Competition***	Numerous Competitors	2	Few Competitors	*Mostly the competitors are different depending upon the market. Only 2-3 consistent competitors. At initial concept / prototyping stage competition is intense. After initial awards and the product reaches maturity the competition is much less. Since the market has contracted they are now going up against bigger companies that are more technically savvy than in the past. Three markets (embedded electronics): Telecom, Military, small opportunities.*
1.50	***1.1.2 Stability/Emerging Threats***	Unpredictable Threats	1	Stable/ Few Threats	***Unpredictability:*** *Market changed radically after the "dot.com" bust. "Systems" business was at 75% is now at 25%. The PCB (printed circuit boards) was at 25% and is now at 75%. This indicates a level of unpredictability. Equipment vendors are beginning to sell heavily in China (**Pac Rim is an emerging threat**). An area of **personnel risk** since it is a small company is the potential loss of key employees with extensive product/process knowledge. **Technological risks** include shrinking product lifetimes cycles have shrunk from 5 years to 18 months. Large customers want to move toward standardization & commodity - the company thrives in customization / specialty. Another threat could be changing industry standards. Moore's law: computing power doubles every 18 months which drives to increasing level of complexity, variety, & component density.*
1.2 Regulatory Environment	***1.2.1 Product Regulations***	Many Regulations	4	Few Regulations	*Relatively little regulations: but some include UL testing, NEBS, FCC emissions due to EMI, ROHS*
4.00	***1.2.2 Process Regulations***	Many Regulations	4	Few Regulations	*Relatively little regulations*
1.3 Market Conditions	***1.3.1 Seasonality Effect***	Heavy Seasonality	4	No Seasonality	*Little seasonality just typical "end of year" pushes.*
3.00	***1.3.2 Level of Growth***	No Growth/Shrinking	2	High Growth	*High growth for some years due to Telecom growth, declining market for 5 years, now for the last few years the market has stabilized. Targeting military and Homeland Security for very high growth but these results are still early.*
Business Environment		***Average Score***	**2.83**		

Case Study: Alpha

2.0 Leadership

2.0 Leadership "prescriptive"		**Level 1**	**Score** →	**Level 5**	**Evidence**
2.1 Strategic Planning & Deployment	**2.1.1 Formal Strategy**	"All things to all"	2.5	Clear: Porter's Generic Strategy	*Some comments were "no clear strategy", fragmented, tend to be myopic, ... multiple strategies have used over the last several years. Strategic efforts are being made to launch new product platforms (e.g., OBPS). Those supporting existing platforms and related modified products are experiencing a high degree of frustration in terms of strategy. Lots of energy is spent upfront to "win" the initial business - at this point margins are thin or negative due to unrecovered engineering time. The hopes (risk) are that the on-going business is secured once they become the incumbent - at this point additional business is easier to win and profitability increases. Recently more effort to recoup the upfront investment in R&D. This is particularly problematic in the "high tech" type of industry.* *Goal: pursue intellectual product based products that are niche, non-commodity with custom applications.*
	2.1.2 Deployment	few know / little involvement	2	widely understood & clear link to actions	*If there is a strategy little evidence that it is consistently deployed. This is particularly true for those that are engaged with current product platforms. High degree of latitude for managers and key professionals which appears to make strategic coordination across functions very difficult.*
2.2 Culture of Empowerment	**2.2.1 Level of Participation**	Restricted Involvement	2.5	High level of Involvement	*Traditionally have hired the "best and brightest engineers - senior professionals and managers are given lots of latitude to pursue things of interest in areas of concern to the business. Clearly participants exhibit a comfortableness in debating issues important to the company. Kaizens events are just starting to include meaningful involvement of the shop floor employees. Historically, they have not relied very heavily on shop floor involvement (2). However, high level of participation found to mangers and technical professionals(4)*
	2.2.2 Effectiveness of Participation	Little evidence of impact	1.5	Evidence of substantial Impact	*A few examples on a per job basis but limited examples of substantial plant wide achievements. Results are highly dependent upon individuals.*

Leadership ***Average Score*** **2.13**

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Case Study: Alpha

3.0 Customer / Market Focus

3.0 Customer / Market Focus "prescriptive"		**Level 1**	**Score** →	**Level 5**	**Evidence**
3.1 Translation of Requirements	**3.1.1 Design/Order**	Informal / Unstructured	3	intentional and formal	*Design - Product functional requirements are clearly defined - many components are specified by the design. (4). Order - requirements are not nailed down as clearly. PO's/contracts don't have a change control mechanism however changes are routinely done while the product is being produced during initial runs. Another example is branding/label definitions (2).*
3.00	**3.1.2 Feedback/Reaction**	few know / little involvement	3	widely understood & clear link to actions	*Customer feedback is available and is positive for sales/design. Clearer linkage on the design side than on the operations side. Customer feedback on operations is not as clear.*
3.2 Positioning / Value	**3.2.1 Customer Value**	No Clear way to identify (informal)	2	Clearly drives all actions (structured)	*Clearly they value quick response from concept to prototype build (4). Opportunities appear in terms of typical operational measures (2) like On-Time Shipments (70-80%), Repair Turn around time (25 days vs 15 days target). Due to increases in product complexity the product is more difficult to repair.*
2.50	**3.2.2 Dimensions of Performance**	No Sense of Relative Priorities	3	Clear Understanding	*Early in the product life cycle the focus is on product functionality, rapid response to customer requests as product matures more operational performance measures tend to dominate (i.e., DPMO, On-time shipments, turn around time on returns). Quality is the big issue. Quick response on customer issues means a lot. Quality is #1, Delivery is close #2 but the order of importance depends upon customer. These are negatives if they are not present - but not so much differentiators. Possible source of positive differentiator is the combination of speed and quality/reliability during prototyping.*

Customer/ Market Focus ***Average Score*** **2.75**

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4.0 Information & Knowledge Management

4.0 Information & Knowledge Management *"descriptive"*		***Level 1***	***Score***	***Level 5***	***Evidence***
4.1 Access to Information & Knowledge	***4.1.1 Availability of Data to Support Decision Making***	Difficult to obtain & interpret	3	Readily available & understand	*Since private company many are not exposed to financial measures, shop floor measures are available via information system. Monthly meeting on inventory turns, top 10 customers, revenue, …Over the last 2-3 years there has been more access to routine measures.*
2.75	***4.1.2 Availability of Product/Process Knowledge***	Difficult to obtain & interpret	2.5	Readily available & understand	*Professional level process knowledge is not well documented. Exception is the Shop Floor database system which is primarily targeted toward shop floor support. Some report writing and query abilities make it useful for manufacturing engineering/managers. However many work processes are not standardized and not well documented - particularly the "above the shop floor" white collar processes. Heavy reliance upon knowledge and skills which reside in key individuals.*
4.2 Supportive of Improvement Efforts	***4.2.1 Operations Data/Information***	Difficult to obtain & interpret	1.5	Readily available & understood	*Lots of good data but not very effective at driving hard actions against where the data indicates biggest opportunities. Follow-up appears to be limited due to organizational barriers and resistance to change. Limited resources having to decide between working on improvements and getting out today's work.*
1.75	***4.2.2 Financial Data/Information***	Difficult to obtain & interpret	2	Readily available & understand	*Cost accounting system used labor hours as a driver for allocating overhead. Approximately 65% of head count is salaried. Have not yet correlated operational improvements to financial results.*

Information & Knowledge Management ***Average Score*** **2.25**

5.0 Human Resources

5.0 Human Resources *"prescriptive"*		***Level 1***	***Score***	***Level 5***	***Evidence***
5.1 Maturity in Teaming	***5.1.1 Level of Team Success***	Limited / Informal	2	Frequent / Formal	*Team formation tends to be informal and relatively infrequent. Little leadership has emerged out of the hourly ranks in terms of increasing continuous improvement capacity. There is a need to develop more trainers.*
2.00	***5.1.2 Qualities Considered in Hiring/Promotion***	Task Skills dominate	2	Balance Between Task & Teaming Skills	*Personal task skills dominate.*
5.2 Employee Skill Level	***5.2.1 Level of Cross Functional Mastery***	Primarily within function	3	Mastery of a variety of skills is widely deployed	*Shop floor cross functional training is still early (2). Among managers and professionals it is more (4). It helps that the company is relatively small - 160 employees. Reluctance to embed design engineers within manufacturing and vice versa.*
3.00	***5.2.2 Mastery of Key Skills***	Not identified and/or inexperience	3	Identified & clear strengths exist	*Needed skill includes "cross section" analysis and management of suppliers. Managers and professionals are allowed to develop areas of professional expertise. Individuals are responsible for their own development. However tends to be more reactive than pro-active.*

Human Resources ***Average Score*** **2.5**

Case Study: Alpha

6.0 Development of Products and Processes

6.0 Development of Products & Processes *"prescriptive"*		Score: **Level 1**		**Level 5**	**Evidence**
6.1 Product Development 3.75	***6.1.1 New Product Development Lead-Time***	Inferior to Competition	4	Superior to Competition	*Reduced LT of product development is a real strength relative to larger more bureaucratic customers. Shrinking product revision cycles is a challenge for manufacturing. New Product Development lead-times is "middle of the road" - modifications and "spin" of custom product is typically "better" than the competition.* *Product lead-times are lengthening due to increasing complexity. - multiple increase in number of layers, number of points per layer.*
	6.1.2 Effectiveness of Product Development	Inferior to Competition	3.5	Superior to Competition	*Generally appears to be effective, but lots of inefficiencies in accomplishing it. Averages 2.5 ECOs per day which is difficult for manufacturing but may just indicate the customization nature of their business direction. It could be that some of these changes are avoidable. Lack of a formal change control process makes it difficult to assess the relative cost/benefit. Prototypes go to manufacturing without a full set of specs. It is not clear at what point the customers should pay for "changes." This may represent additional opportunity for revenue generation enabled by more carefully defining deliverables, which in turn make it clearer when customers are requesting something different.* *Apparently sustained advantage is possible "your product / unique", right time @ right price. Ability to customize is important. It appears that there is not a clear gate for transitioning into mature production mode. There is a 65 point check off for new products, but does not appear to be followed through. Opportunity is to do a better job moving new products into production. Implementation lacks the final polish at the level of detail that manufacturing requires. Opportunity for more effective manufacturing engagement early in the design.*
6.2 Process Development 3.25	***6.2.1 New Process Development Lead-Time***	Inferior to Competition	3.5	Superior to Competition	*Numerous examples including selective soldering, automated inspection (optical and X-Ray).*
	6.2.2 Effectiveness of New Process Development	Inferior to Competition	3	Superior to Competition	*Opportunity for more effective manufacturing engagement early in the design. Appears to be frustration in the implementation of soft changes (e.g., training people). Changes across functional lines is difficult.*

Development of Products & Processes ***Average Score*** **3.50**

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Case Study: Alpha

7.0 Product & Process Characterization

7.0 Product & Process Characterization *"descriptive"*		Score: **Level 1**		**Level 5**	**Evidence**
7.1 Product Characterization 3.25	***7.1.1 Product Lifetime***	Short	3	Long	*Customers expect product lifetimes in excess of 5 years.- Long useful life (5)- but frequent updates and versions (1). Time between ECO releases is getting shorter. 2 year warranty. Shrinking lifecycles due to Moore's law….*
	7.1.2 Product Volume	Low	2	High	
	7.1.3 Product Complexity	Low	4	High	*Greater customer requirements are resulting in higher density PCBs*
	7.1.4 Product Variety	Low	4	High	*Products are standard designs, std + custom, new products*
7.2 Process Characterization 1.50	***7.2.1 Process Capacity***	Excess	1.5	Minimal	*Generally excess capacity in both labor and space. Historically there has been an aversion to running 2 shifts.*
	7.2.2 Layout of Processes	Functional	1	Cellular	*Highly functional due to technical nature of each function.*
	7.2.3 Process Integration	Low	2	High	*Focus is essentially on assembly and test.*
7.3 Product-Process Characterization 4.00	***7.3.1 Goldratt's VAT***	Unclear Fit	4	Clear Fit	*T plant with some characteristics of a plant.*
	7.3.2 Hayes-Wheelwright Matrix	Unclear Fit	4	Clear Fit	*I. Disconnected Line (batch) and II. Multiple products low volume.*

Product & Process Characterization ***Average Score*** **2.83**

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Case Study: Alpha

8.0 Management of Extended Enterprise

8.0 Management of Extended Enterprise "prescriptive"		Level 1	Score	Level 5	Evidence
8.1 Supply Chain Management	**8.1.1 Product Requirements**	Unclear	3	Clear	*Ordering by vendors PN goes well. Noted it is common for engineering to spec particular vendors. Fabricated metal specs does not go as well. PCB Quality specs of many of their incoming components are not well quantified beyond the basic rating of components. This has been recognized as a gap and the Quality organization is working on developing an approach to more formally document the quality of incoming product. Also there appears to be an opportunity to do a better job linking repair dispositions to component quality and ultimately to evaluation of vendor performance. Some suspension that many of the failures at First Pass yield may ultimately be due to component quality... however no data exists to substantiate or reject this hypothesis.*
3.00	**8.1.2 Ordering & Inventory Requirements**	Unclear	3	Clear	*Frequent expediting occurs due to customer shifts. MRP work order system used within the plant - "push." 280 PN's are required for some products. and in general adds to he lead-time to get orders through the plant. Work order releases tend to be 50-300 in large part due to 1-6 hour set-up times on the SMT.Worker releases greater than the size of the customer order ends up going into the "pool" of WIP. This pool in WIP often stagnates results in unnecessary moving and handling, increased difficulty in finding material needed for sactual orders, needless complexity that plant supervisors must deal with. Reduciung work order sizes using the current system will increase the number of orders sent to the plant. Planning Kaizen soon to reduce the set-ups on the SMT. However, if set-up reduction is done without increasing the number of set-ups then it will make the "pool" of WIP only worse. There should be a clear distinction between using MRP to order and schedule purchased materials from how you internally schedule the plant*
8.2 Distribution Chain Management	**8.2.1 Finished Goods Management**	Unclear	4	Clear	
3.50	**8.2.2 Order Fulfillment Management**	Not meeting Customer Desires	3	Regularly Meeting Customer Desires	

Management of Extended Enterprise *Average Score* 3.25

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Case Study: Alpha

9.0 Approach to Continuous Improvement

9.0 Approach to Continuous Improvement "Prescriptive"		Level 1	Score	Level 5	Evidence
9.1 Performance Measures	**9.1.1 Strategic Alignment of Operational Measures**	fuzzy connection	2	clearly articulated	
	9.1.2 Balanced & Multi-dimensional	single dimension (e.g., cost)	3	multi-dimensional & balanced	*FPY @ Functional test = 92% … Actual non repairable = 2-3%, 13% go to repair.*
9.2 Process Focus	**9.2.1 Identification of Key Processes**	unsupported	4	documented & communicated	*Does speed verse flexibility impact the type of equipment purchased?*
	9.2.2 Constraints	unknown	3	known & managed	
	9.2.3 Emphasis on Variability & CT Reduction	none	3	drives action	
9.3 Use of World Class Practices	**9.3.1 Continuous Improvement Approach**	informal	2	formal & intentional	*Kaizen Events focusing on standardization*
	9.3.2 Effectiveness	unclear	2	clear & documented	*Continuous improvement efforts are functionally focused not cross functional. This is true both on the shop floor and above the shop floor. They are not satisfied with the results to date.*
9.4 Quality System	**9.4.1 Formal System**	Informal & unstructured	4	formal & registered	*ISO 9000*
	9.4.2 Effectiveness	conformance driven	2	performance driven	*A more intentional focus is needed in order to move the quality system from being compliance driven to effectiveness.*

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Approach to Continuous Improvement *Average Score* 2.78

Case Study: Alpha

10.0 Enterprise Financial Health

10.0 Enterprise Financial Health *"Descriptive"*		Score: Level 1 → Level 5			***Evidence***
10.1 Ability to Invest in Assets	***10.1.1 Capital Availability***	not possible / severely restricted	4	Adequate	*Investment dollars are available to fund good projects.*
10.2 Liquidity	***10.2.1 Cash Flow***	severely restricted	4	sufficient	*Financial condition does not appear to hamper daily operations.*

Enterprise Financial Health ***Average Score*** 4.00

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Case Study: Alpha

Summary of MET Survey Scoring

1.0 Business Environment			Score	Average for Category	Average for Taxon
	1.1 Competitive Environment	1.1.1 Intensity of Competition	*2*	1.50	2.83
		1.2.1 Stability/Emerging Threats	*1*		
	1.2 Regulatory Environment	1.2.1 Product Regulations:	*4*	4.00	
		1.2.2 Process Regulations:	*4*		
	1.3 Market Conditions	1.3.1 Seasonality Effect	*4*	3.00	
		1.3.2 Level of Growth	*2*		
2.0 Leadership					
	2.1 Strategic Planning & Deployment	2.1.1 Formal Strategy	*2.5*	2.25	2.13
		2.1.2 Strategy Deployment	*2*		
	2.2 Culture of Empowerment	2.2.1 Level of Participation	*2.5*	2.00	
		2.2.2 Effectiveness of Participation	*1.5*		
3.0 Customer / Market Focus					
	3.1 Translation of Requirements	3.1.1 Design/Order	*3*	3.00	2.75
		3.1.2 Feedback/Reaction	*3*		
	3.2 Positioning / Value	3.2.1 Customer Value	*2*	2.50	
		3.2.2 Dimensions of Performance	*3*		
4.0 Information System & Knowledge Management					
	4.1 Access to Information & Knowledge	4.1.1 Availability to Data/Information to Support Decision Making	*3*	2.75	2.25
		4.1.2 Availability of Product/Process Knowledge	*2.5*		
	4.2 Supportive of Improvement Efforts	4.2.1 Operations Data/Information	*1.5*	1.75	
		4.2.2 Financial Data/Information	*2*		
5.0 Human Resources					
	5.1 Maturity in Teaming	5.1.1 Level of Team Successes	*2*	2.00	2.50
		5.1.2 Team Qualities Considered Strongly in Hiring/Promotion	*2*		
	5.2 Employee Skill Level	5.2.1 Cross Functional Encourgement	*3*	3.00	
		5.2.2 Opportunties for Developing Additional Skills	*3*		
6.0 Development of Products & Processes					
	6.1 Product Development	6.1.1 New Product Development Time	*4*	3.75	3.50
		6.1.2 Effectiveness of New Products Relative to Opportunity	*3.5*		
	6.2 Process Development	6.2.1 New Process Development Time	*3.5*	3.25	
		6.2.2 Effectiveness of New Processes Relative to Opportunity	*3*		
7.0 Product & Process Characterization					
	7.1 Product Characterization	7.1.1 Product Lifetime	*3*	3.25	2.83
		7.1.2 Product Volume	*2*		
		7.1.3 Product Complexity	*4*		
		7.1.4 Product Variety	*4*		
	7.2 Process Characterization	7.2.1 Process Capacity	*1.5*	1.50	
		7.2.2 Layout of Processes	*1*		
		7.2.3 Process Integration	*2*		
	7.3 Product-Process Characterization	7.3.1 Goldratt's VAT Logical Product-Process	*4*	4.00	
		7.3.2 Hayes-Wheelwright Matrix	*4*		
8.0 Management of Extended Enterprise					
	8.1 Supply Chain Management	8.1.1 Management of Requirements (Product & Ordering)	*3*	3.00	3.25
		8.1.2 Management of Incoming Inventory	*3*		
	8.2 Distribution Chain Management	8.2.1 Management of Finished Goods Inventory	*4*	3.50	
		8.2.2 Management of Order Fullfillment	*3*		
9.0 Approach to Continuous Improvement					
	9.1 Performance Measures	9.1.1 Strategic Alignment of Operational Measures	*2*	2.50	2.78
		9.1.2 Balanced & Multi-dimensional	*3*		
	9.2 Process Focus	9.2.1 Key Process Identification	*4*	3.33	
		9.2.2 Constraints	*3*		
		9.2.3 Emphasis on Variability & CT Reduction	*3*		
	9.3 Use of Specific World Class Practices	9.3.1 Formal Adoption of a CI Approach	*2*	2.00	
		9.3.2 Demonstration of Effectiveness	*2*		
	9.4 Quality System	9.4.1 Formal System	*4*	3.00	
		9.4.2 Demonstration of Effectiveness	*2*		
10.0 Enterprise Financial Health					
	10.1 Capital Availability	10.1.1 Capital Availability	*4*	4.00	4.00
	10.2 Liquidity	10.2.1 Cash Flow	*4*	4.00	

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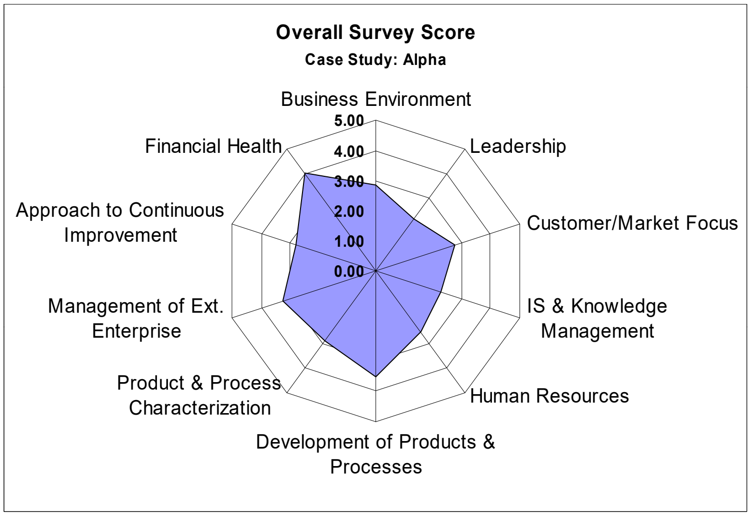
Case Study: Alpha

MET Scoring Across Major Attributes



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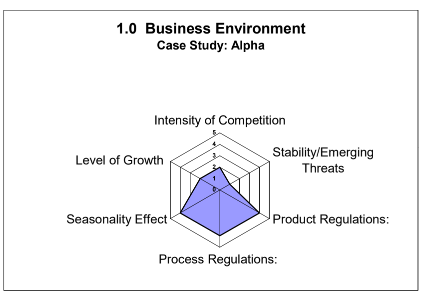
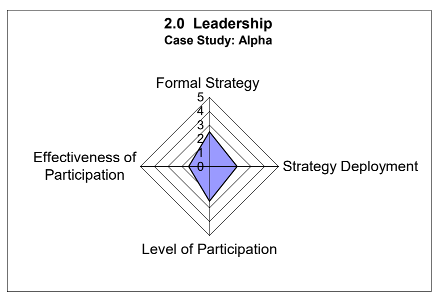
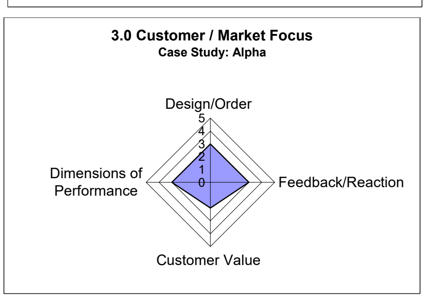
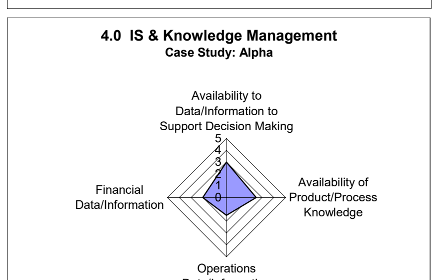
Case Study: Alpha

Scoring within Major Attributes









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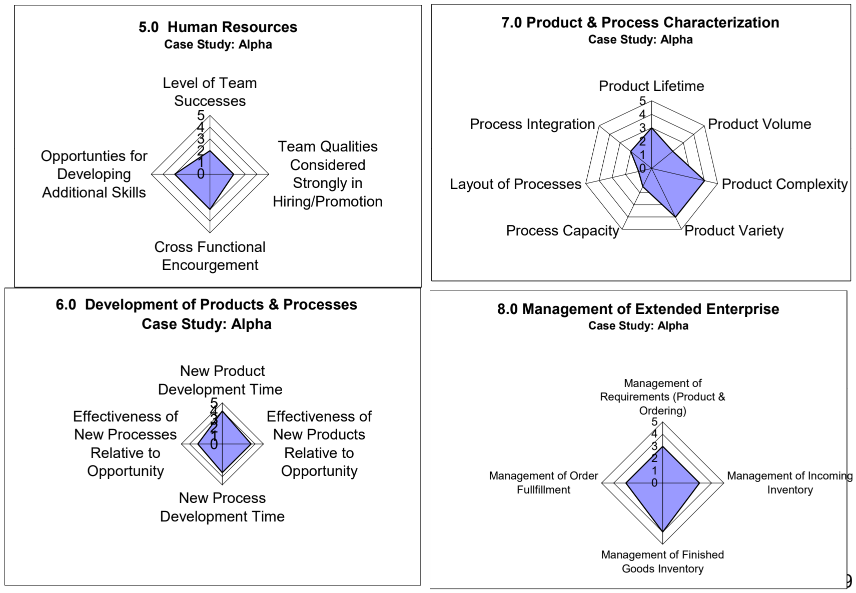
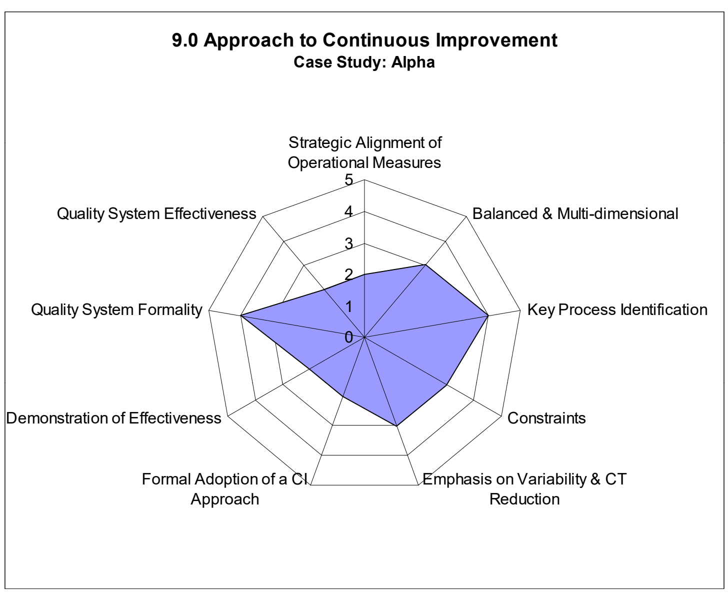
Case Study: Alpha

Scoring within Major Attributes



Case Study: Alpha

Scoring within Major Attributes



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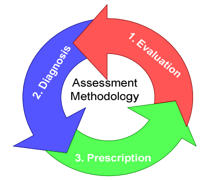
Prioritization of UDEs Identified During the MET Survey			Case: Alpha
	UDE	Overall	Cummulative Percentage
1	***Not a clearly defined and embraced strategy for how manufacturing should best support sustained advantage.***	***50***	***25%***
2	***Multiple changes (e.g., product configuration and changes in design) which result in chaos in manufacturing.***	***35***	***43%***
3	***Percentage of On-Time shipments is running @ 75% (below customer expectation)***	***25***	***55%***
4	Lack of communication between manufacturing and design	15	63%
5	Hourly workers do not feel like they are respected/listened to … Mismatch between hourly employee needs and level of direction provided.	15	70%
6	Data collection to support a reliable measurement of the quality of supplied product.	15	78%
7	Changeovers (e.g., SMT) take too long	15	85%
8	Difficulty to getting root causes solutions on problem areas pointed at by the data.	10	90%
9	Turn around on repairs not meeting internal objective	5	93%
10	Takes too long to get a built prototype	5	95%
11	Protoypes have too many bugs	5	98%
12	Manufacturing concerns are not uncovered early in the prototype phase.	5	100%
13	Difficulty on recognizing (confusion) the difference between prototyping and production expectations at the shop floor.	0	100%
14	Current process for supporting ECOs and spins are more costly than we would like.	0	100%
15	Expediting of customer orders is common.	0	100%
16	"Pool" in manufacturing (not voted)	0	100%
	Total	200	

Case Study: Alpha

UDEs Selected for Probing During Diagnosis Phase

Highest Priority UDEs for Use in CRT Construction	
UDE-1	***Not a clearly defined and embraced strategy for how manufacturing should best support sustained advantage.***
UDE-2	***Multiple changes (e.g., product configuration and changes in design) which result in chaos in manufacturing.***
UDE-3	***Percentage of On-Time shipments is running @ 75% (below customer expectation)***

Case Study: Alpha



Diagnosis Stage

Objective: Translate Undesirable Effects (UDEs) into Root Cause(s) through the use of Current Reality Tree.

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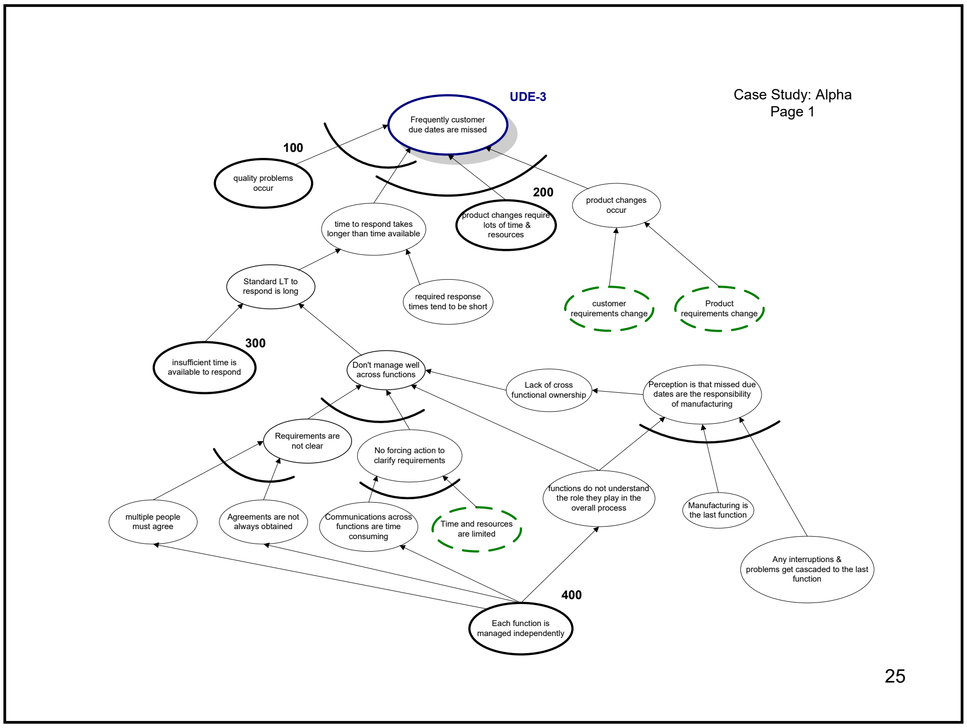
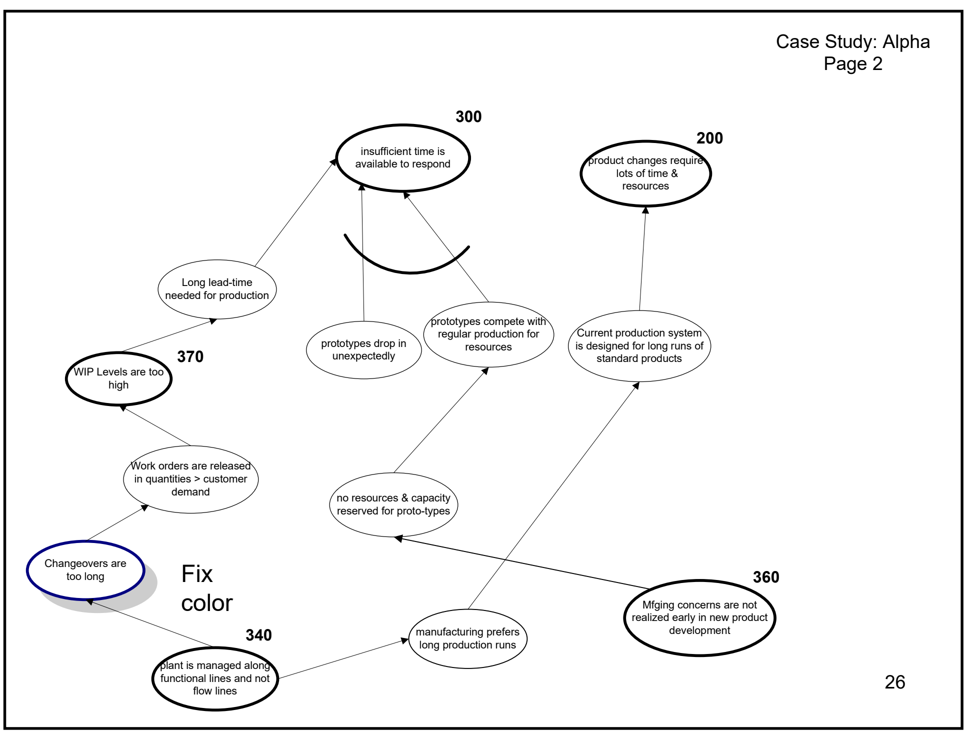
Current Reality Tree: Legend

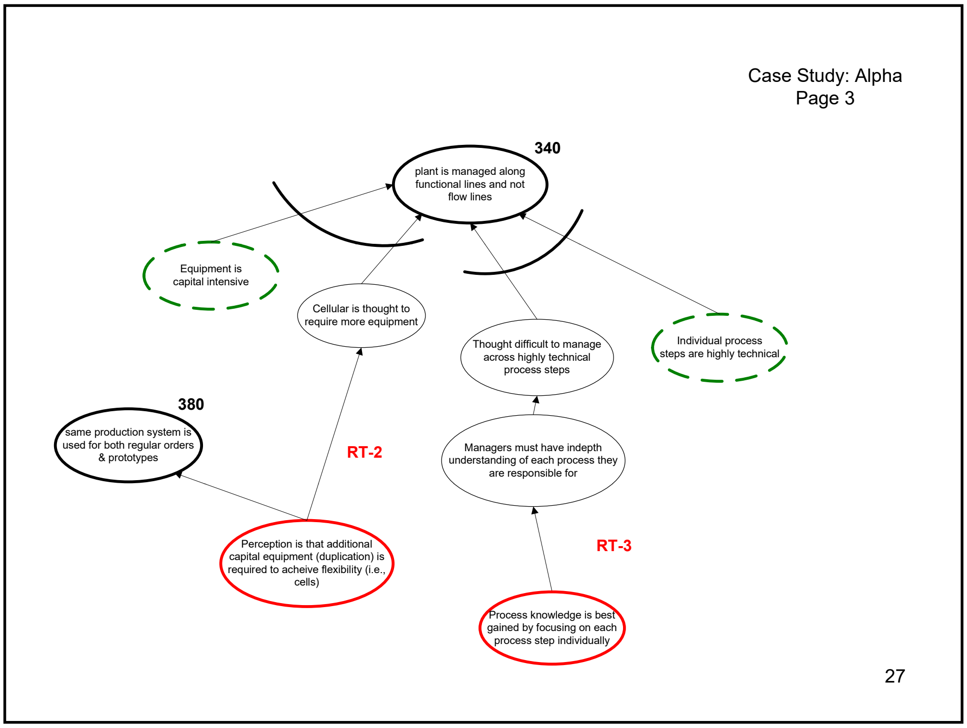
Undesirable Effect

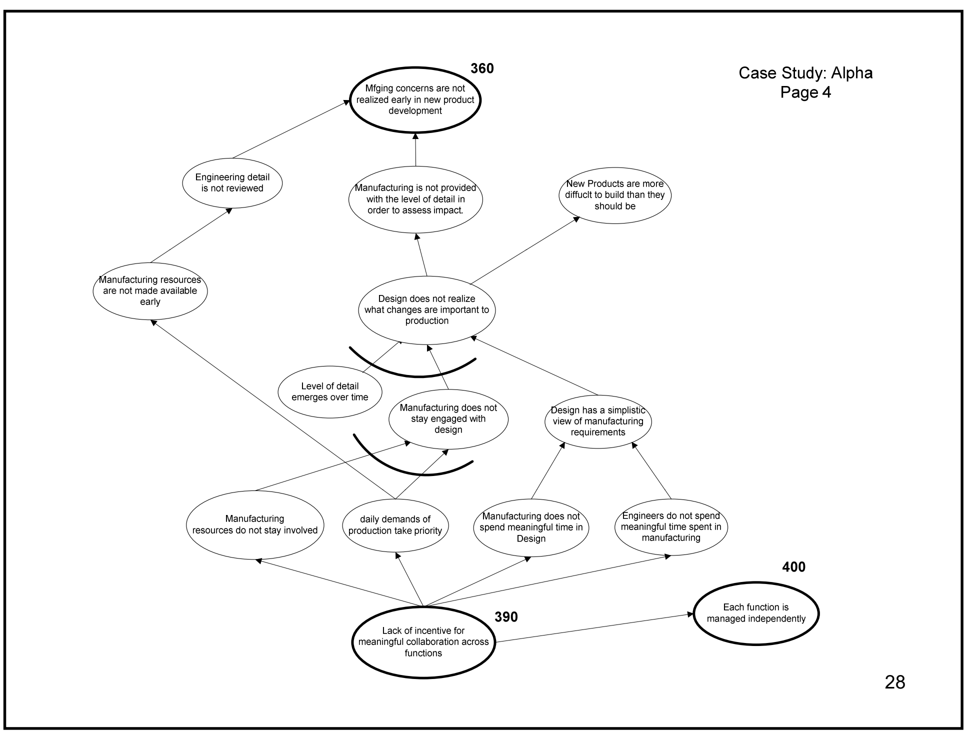
UDE-2

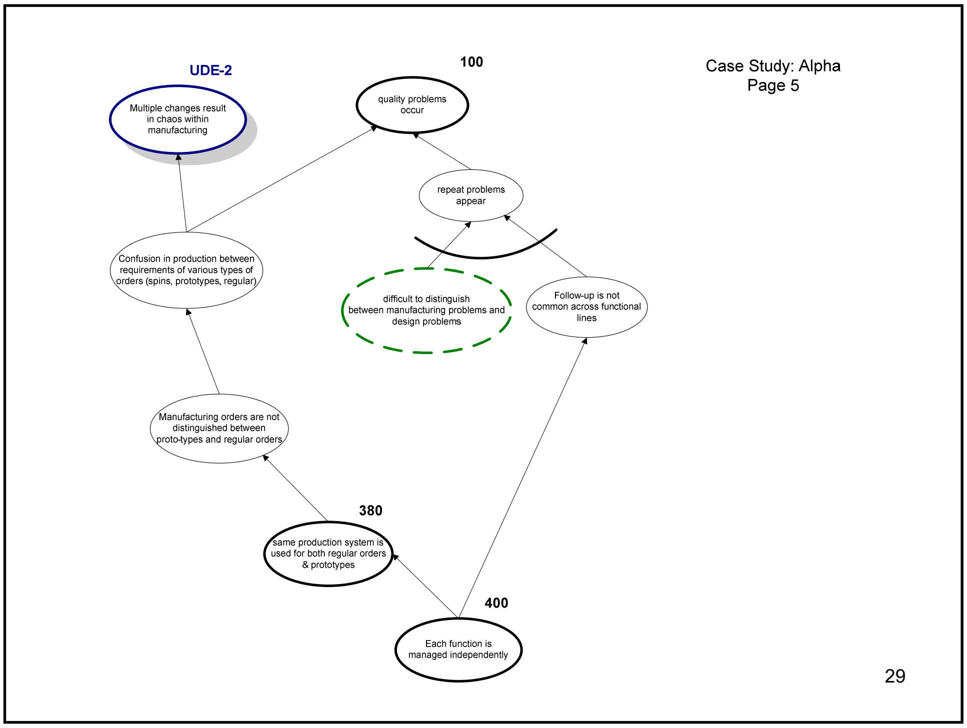
Cause and Effect Linkage

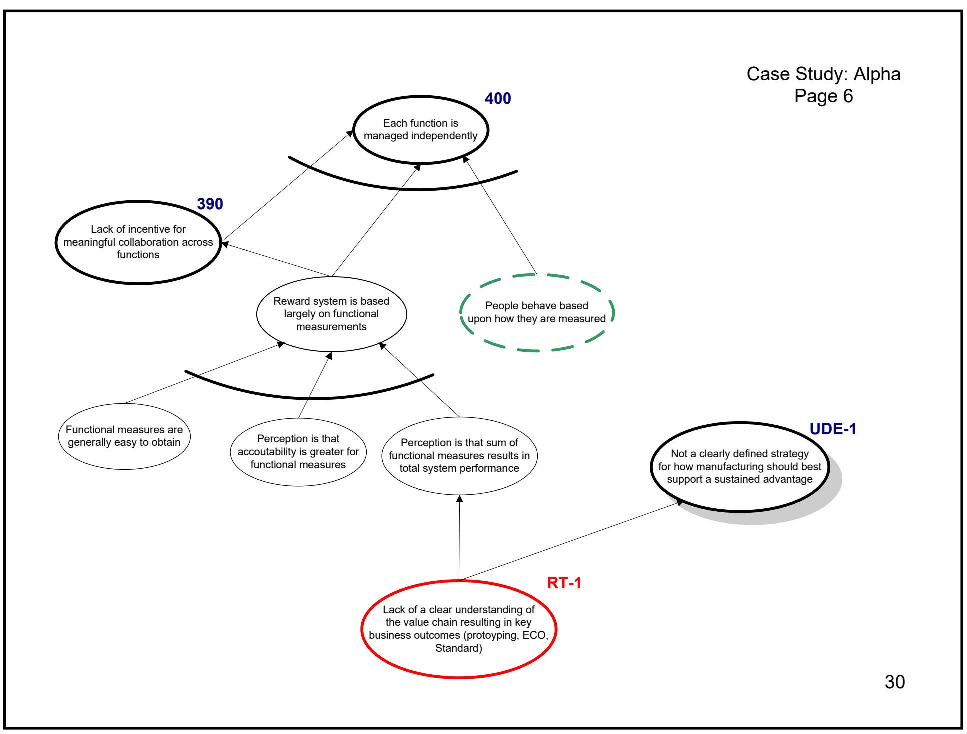

Case Study: Alpha
Page 1
UDE-3
Frequently customer due dates are missed
100
quality problems occur
time to respond takes longer than time available
200
product changes require lots of time & resources
product changes occur
Standard LT to respond is long
required response times tend to be short
customer requirements change
Product requirements change
300
insufficient time is available to respond
Don't manage well across functions
Lack of cross functional ownership
Perception is that missed due dates are the responsibility of manufacturing
Requirements are not clear
No forcing action to clarify requirements
functions do not understand the role they play in the overall process
Manufacturing is the last function
multiple people must agree
Agreements are not always obtained
Communications across functions are time consuming
Time and resources are limited
Any interruptions & problems get cascaded to the last function
400
Each function is managed independently
25


Case Study: Alpha
Page 2
300
insufficient time is available to respond
200
product changes require lots of time & resources
Long lead-time needed for production
prototypes drop in unexpectedly
prototypes compete with regular production for resources
Current production system is designed for long runs of standard products
370
WIP Levels are too high
Work orders are released in quantities > customer demand
no resources & capacity reserved for proto-types
Changeovers are too long
Fix color
360
Mfging concerns are not realized early in new product development
340
plant is managed along functional lines and not flow lines
manufacturing prefers long production runs
26


Case Study: Alpha
Page 3
340
plant is managed along functional lines and not flow lines
Equipment is capital intensive
Cellular is thought to require more equipment
Thought difficult to manage across highly technical process steps
Individual process steps are highly technical
380
same production system is used for both regular orders & prototypes
RT-2
Managers must have indepth understanding of each process they are responsible for
RT-3
Perception is that additional capital equipment (duplication) is required to acheive flexibility (i.e., cells)
Process knowledge is best gained by focusing on each process step individually
27


360
Mfging concerns are not realized early in new product development
Case Study: Alpha
Page 4
Engineering detail is not reviewed
Manufacturing is not provided with the level of detail in order to assess impact.
New Products are more difficult to build than they should be
Manufacturing resources are not made available early
Design does not realize what changes are important to production
Level of detail emerges over time
Manufacturing does not stay engaged with design
Design has a simplistic view of manufacturing requirements
Manufacturing resources do not stay involved
daily demands of production take priority
Manufacturing does not spend meaningful time in Design
Engineers do not spend meaningful time spent in manufacturing
400
Each function is managed independently
390
Lack of incentive for meaningful collaboration across functions
28


Case Study: Alpha
Page 5
UDE-2
Multiple changes result in chaos within manufacturing
100
quality problems occur
repeat problems appear
Confusion in production between requirements of various types of orders (spins, prototypes, regular)
difficult to distinguish between manufacturing problems and design problems
Follow-up is not common across functional lines
Manufacturing orders are not distinguished between proto-types and regular orders
380
same production system is used for both regular orders & prototypes
400
Each function is managed independently
29


Case Study: Alpha
Page 6
400
Each function is managed independently
390
Lack of incentive for meaningful collaboration across functions
Reward system is based largely on functional measurements
People behave based upon how they are measured
Functional measures are generally easy to obtain
Perception is that accoutability is greater for functional measures
Perception is that sum of functional measures results in total system performance
UDE-1
Not a clearly defined strategy for how manufacturing should best support a sustained advantage
RT-1
Lack of a clear understanding of the value chain resulting in key business outcomes (protoyping, ECO, Standard)
30

Case Study: Alpha

Summary UDEs and Root Causes

UDEs	Root Causes
• **UDE-1:** Not a clearly defined and embraced strategy for how manufacturing should best support a sustained advantage.	• **RT-1:** Lack of clear visibility of the value chain of activities required to support key business outcomes.
• **UDE-2 :** Multiple changes (e.g., changes in product design and changes in design) result in chaos within manufacturing.	• **RT-2:** Perception is that additional capital equipment is needed to achieve the desired flexibility (i.e., cells)
• **UDE-3:** Percentage of on-time shipments is running @ 75% which is below customer expectations	• **RT-3:** Process knowledge is best gained by focusing on each step individually.

Note: There is not a one-to-one relationship between the three UDEs and the three root causes. The relationships are defined by the CRT.

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Case Study: Alpha

Prescription Stage

Objective: *develop a set of recommendations which target elimination of root causes identified during diagnosis. The recommendations are developed guided by appropriate elements selected from within the PST*

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Case Study: Alpha

Relationship of Root Causes to Best Practices Between Bolden's Taxonomy
Case Study: Alpha
11-Jun-07

Production System Taxonomy (PST)				Root Causes from the Current Reality Tree												
Bolden's Modified Taxonomy				RT-1 Lack of clear visibility in the value chain required to to support key business outcomes (prototyping, ECO, Standard Production)				RT-2 Perception is that additional capital equipment (duplication) is needed to achieve flexibility (cells).				RT-3 Process knowledge is best gained by focusing on each process step individually				Element Total
Problem Domain	Strategic Emphasis	Reference Number	"Best Practice"	CW	RS	TH	Sum of RT-1	CW	RS	TH	Sum of RT-2	CW	RS	TH	Sum of RT-3	
Design and Production	Improved Quality	1.A-1	Quality Standards				0				0				0	0
		1.A-2	SPC				0				0				0	0
		1.A-3	TPM				0				0				0	0
		1.A-4	QFD				0				0				0	0
		1.A-5	Poke-Yoke				0				0				0	0
							0				0				0	0
Inventory and Stock		2.A-1	Supply Chain Partnering				0				0				0	0
		2.A-2	Customer Feedback				0				0				0	0
		2.A-3	Conformance Checks				0				0				0	0
							0				0				0	0
Work Organization		3.A-1	Quality improvement teams				0				0	15			15	15
		3.A-2	Operator responsibility				0				0				0	0
		3.A-3	Quality feedback to operators				0				0				0	0
		3.A-4	Quality training				0				0				0	0
		3.A-5	Ergonomic design				0				0				0	0
							0				0				0	0
Wider Organization		4.A-1	Total quality management				0				0			10	10	10
		4.A-2	Quality awards				0				0				0	0
		4.A-3	Internationally Competitive Benchmarking for Quality				0				0				0	0
							0				0				0	0
Design and Production	Reduced Cost	1.B-1	Reduced WIP	20	15	15	50	10	10	10	30				0	80
		1.B-2	JIT Production				0	5			5				0	5
		1.B-3	Process Mapping	10		25	35				0		30		30	65
		1.B-4	Design for Manufacturability				0				0			10	10	10
		1.B-5	Re-usability				0				0				0	0
		1.B-6	Value Engineering				0				0				0	0
							0				0				0	0
Inventory and Stock		2.B-1	Reduced Inventory				0		10		10				0	10
		2.B-2	Single Sourcing				0				0				0	0
		2.B-3	JIT Inventory Control				0				0				0	0
		2.B-4	Inventory Control				0				0				0	0
		2.B-5	Forecasting				0				0				0	0
		2.B-6	Logistics Management				0				0				0	0
							0				0				0	0
Work Organization		3.B-1	Downsizing				0				0				0	0
		3.B-2	De-layering				0				0				0	0
		3.B-3	Outsourcing				0				0				0	0
		3.B-4	Flexible Labor Force		5		5	10	20		30		10		10	45
							0				0				0	0
Wider Organization		4.B-1	Lean production		10	10	20		10	20	30		20	10	30	80
		4.B-2	Cost management				0				0				0	0
		4.B-3	Financial performance				0				0				0	0
		4.B-4	Time based management				0				0				0	0
		4.B-5	Benchmarking: costs				0				0				0	0
		4.B-6	Balanced Scorecard	10	10		20				0				0	20
		4.B-7	Link Mfging to Strategy	20	20	10	50				0				0	50

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Case Study: Alpha

Production System Taxonomy (PST)				Root Causes from the Current Reality Tree												
Bolden's Modified Taxonomy				RT-1 Lack of clear visibility in the value chain required to to support key business outcomes (prototyping, ECO, Standard Production)				RT-2 Perception is that additional capital equipment (duplication) is needed to achieve flexibility (cells).				RT-3 Process knowledge is best gained by focusing on each process step individually				Element Total
Problem Domain	Strategic Emphasis	Reference Number	"Best Practice"	CW	RS	TH	Sum of RT-1	CW	RS	TH	Sum of RT-2	CW	RS	TH	Sum of RT-3	
							0				0				0	0
Design and Production	Responsiveness to Customer	1.C-1	Rapid prototyping				0				0				0	0
		1.C-2	Concurrent engineering	15	10	10	35				0				0	35
		1.C-3	Customer involvement in design				0				0				0	0
		1.C-4	LT reduction	25	5		30	25		15	40		20		20	90
		1.C-5	Agile manufacturing				0				0				0	0
		1.C-6	SMED				0	10		15	25				0	25
							0				0				0	0
Inventory and Stock		2.C-1	Predicting customer requirements				0				0				0	0
		2.C-2	Maintaining stock levels				0				0				0	0
							0				0				0	0
Work Organization		3.C-1	Flexible work organization				0				0				0	0
		3.C-2	After sales support				0				0				0	0
		3.C-3	Cellular manufacturing		20		20	20	30	20	70		20		20	110
							0				0				0	0
Wider Organization		4.C-1	Customer Focus				0				0				0	0
		4.C-2	Market research				0				0				0	0
		4.C-3	Customer surveys				0				0				0	0
		4.C-4	Bench. for customer Responsiveness				0				0				0	0
		4.C-5	BPR			10	10				0				0	10
							0				0				0	0
Design and Production	Improved Technology	1.D-1	CAPP				0				0				0	0
		1.D-2	CIM				0				0				0	0
		1.D-3	Automation				0				0				0	0
		1.D-4	CAD & engineering				0				0				0	0
		1.D-5	New Process Development				0				0			10	10	10
							0				0				0	0
Inventory and Stock		2.D-1	Automated storage & retrieval systems				0				0				0	0
		2.D-2	EDI				0				0				0	0
							0				0				0	0
Work Organization		3.D-1	FMS				0				0				0	0
		3.D-2	Group Technology				0				0				0	0
		3.D-3	Computer co-operative work				0				0				0	0
		3.D-4	MRP/ERP				0				0				0	0
							0				0				0	0
Wider Organization		4.D-1	Information Technology strategy				0				0				0	0
		4.D-2	Decision Support Sys.				0				0				0	0
		4.D-3	Technology Benchmarking				0				0				0	0
		4.D-4	Environmental Compatibility				0				0				0	0
		4.D-5	Six Sigma			20	20			10	10	25			25	55
							0				0				0	0
Design and Production	Employee Development	1.E-1	Job Rotation				0				0				0	0
		1.E-2	Multi-Skilling				0	15		5	20	25		20	45	65
		1.E-3	Psychomterics				0				0				0	0
		1.E-4	Appraisal				0				0				0	0
		1.E-5	Training & development		5		5		20	5	25			20	20	50
		1.E-6	Suggestion schemes				0				0				0	0
		1.E-7	Attitude surveys				0				0				0	0
		1.E-8	Staff/Management Rotation				0				0				0	0
		1.E-9	Safety management				0				0				0	0
							0				0				0	0
Inventory and Stock		2.E-1	Product team (purchasing and distribution)				0				0				0	0
							0				0				0	0
Work Organization		3.E-1	Reduce Status Barriers				0				0				0	0
		3.E-2	Team based work				0				0	25		20	45	45
		3.E-3	Job Enrichment				0				0				0	0
		3.E-4	Boundary Management				0				0				0	0
							0				0				0	0
Wider Organization		4.E-1	HRM strategy				0				0				0	0
		4.E-2	Empowerment				0				0				0	0
		4.E-3	Performance based pay				0	5			5				0	5
		4.E-4	Culture change				0				0				0	0
		4.E-5	Learning climate				0				0				0	0
		4.E-6	Investors in people				0				0				0	0
		4.E-7	Benchmark people effectiveness				0				0				0	0
			Total	100	100	100	300	100	100	100	300	90	100	100	290	

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Case Study: Alpha

Production System Taxonomy (PST) — Bolden's Modified Taxonomy				Root Causes from the Current Reality Tree (Case Alpha)			
				RT-1 Lack of clear visibility in the value chain required to to support key business outcomes (prototyping, ECO, Standard Production)	**RT-2** Perception is that additional capital equipment (duplication) is needed to achieve flexibility (cells).	**RT-3** Process knowledge is best gained by focusing on each process step individually	**Element Total**
Problem Domain	**Strategic Emphasis**	**Reference Number**	**"Best Practice"**	Score	Score	Score	
Design and Production	Improved Quality	1.A-1	Quality Standards		0	0	0
		1.A-2	SPC		0	0	0
		1.A-3	TPM		0	0	0
		1.A-4	QFD		0	0	0
		1.A-5	Mistake Proofing		0	0	0
					0	0	0
Inventory and Stock		2.A-1	Supply Chain Partnering		0	0	0
		2.A-2	Customer Feedback		0	0	0
		2.A-3	Conformance Checks		0	0	0
					0	0	0
Work Organization		3.A-1	Quality improvement teams		0	15	15
		3.A-2	Operator responsibility		0	0	0
		3.A-3	Quality feedback to operators		0	0	0
		3.A-4	Quality training		0	0	0
		3.A-5	Ergonomic design		0	0	0
					0	0	0
Wider Organization		4.A-1	Total quality management		0	10	10
		4.A-2	Quality awards		0	0	0
		4.A-3	Internationally Competitive Benchmarking for Quality		0	0	0
					0	0	0
Design and Production	Reduced Cost	1.B-1	Reduced WIP	20	30	0	80
		1.B-2	JIT Production		5	0	5
		1.B-3	Process Mapping	10	0	30	65
		1.B-4	Design for Manufacturability		0	10	10
		1.B-5	Re-usability		0	0	0
		1.B-6	Value Engineering		0	0	0
					0	0	0
Inventory and Stock		2.B-1	Reduced Inventory		10	0	10
		2.B-2	Single Sourcing		0	0	0
		2.B-3	JIT Inventory Control		0	0	0
		2.B-4	Inventory Control		0	0	0
		2.B-5	Forecasting		0	0	0
		2.B-6	Logistics Management		0	0	0
					0	0	0
Work Organization		3.B-1	Downsizing		0	0	0
		3.B-2	De-layering		0	0	0
		3.B-3	Outsourcing		0	0	0
		3.B-4	Flexible Labor Force		30	10	45
					0	0	0
Wider Organization		4.B-1	Lean production		30	30	80
		4.B-2	Cost management		0	0	0
		4.B-3	Financial performance		0	0	0
		4.B-4	Time based management		0	0	0
		4.B-5	Benchmarking: costs		0	0	0
		4.B-6	Balanced Scorecard	10	0	0	20
		4.B-7	Link Mfging to Strategy	20	0	0	50
					0	0	0
Design and Production	Responsiveness to Customer	1.C-1	Rapid prototyping		0	0	0
		1.C-2	Concurrent engineering	15	0	0	35
		1.C-3	Customer involvement in design		0	0	0
		1.C-4	LT reduction	25	40	20	90
		1.C-5	Agile manufacturing		0	0	0
		1.C-6	SMED		25	0	25
					0	0	0
Inventory and Stock		2.C-1	Predicting customer requirements		0	0	0
		2.C-2	Maintaining stock levels		0	0	0
					0	0	0
Work Organization		3.C-1	Flexible work organization		0	0	0
		3.C-2	After sales support		0	0	0
		3.C-3	Cellular manufacturing		70	20	110
					0	0	0
Wider Organization		4.C-1	Customer Focus		0	0	0
		4.C-2	Market research		0	0	0
		4.C-3	Customer surveys		0	0	0
		4.C-4	Bench. for customer Responsiveness		0	0	0
		4.C-5	BPR		0	0	10
					0	0	0
Design and Production	Improved Technology	1.D-1	CAPP		0	0	0
		1.D-2	CIM		0	0	0
		1.D-3	Automation		0	0	0
		1.D-4	CAD & engineering		0	0	0
		1.D-5	New Process Development		0	10	10
					0	0	0
Inventory and Stock		2.D-1	Automated storage & retrieval systems		0	0	0
		2.D-2	EDI		0	0	0
					0	0	0
Work Organization		3.D-1	FMS		0	0	0
		3.D-2	Group Technology		0	0	0
		3.D-3	Computer co-operative work		0	0	0
		3.D-4	MRP/ERP		0	0	0
					0	0	0
Wider Organization		4.D-1	Information Technology strategy		0	0	0
		4.D-2	Decision Support Sys.		0	0	0
		4.D-3	Technology Benchmarking		0	0	0
		4.D-4	Environmental Compatibility		0	0	0
		4.D-5	Six Sigma		10	25	55
					0	0	0
Design and Production	Employee Development	1.E-1	Job Rotation		0	0	0
		1.E-2	Multi-Skilling		20	45	65
		1.E-3	Psychomterics		0	0	0
		1.E-4	Appraisal		0	0	0
		1.E-5	Training & development		25	20	50
		1.E-6	Suggestion schemes		0	0	0
		1.E-7	Attitude surveys		0	0	0
		1.E-8	Staff/Management Rotation		0	0	0
		1.E-9	Safety management		0	0	0
					0	0	0
Inventory and Stock		2.E-1	Product team (purchasing and distribution)		0	0	0
					0	0	0
Work Organization		3.E-1	Reduce Status Barriers		0	0	0
		3.E-2	Team based work		0	45	45
		3.E-3	Job Enrichment		0	0	0
		3.E-4	Boundary Management		0	0	0
					0	0	0
Wider Organization		4.E-1	HRM strategy		0	0	0
		4.E-2	Empowerment		0	0	0
		4.E-3	Performance based pay		5	0	5
		4.E-4	Culture change		0	0	0
		4.E-5	Learning climate		0	0	0
		4.E-6	Investors in people		0	0	0
		4.E-7	Benchmark people effectiveness		0	0	0

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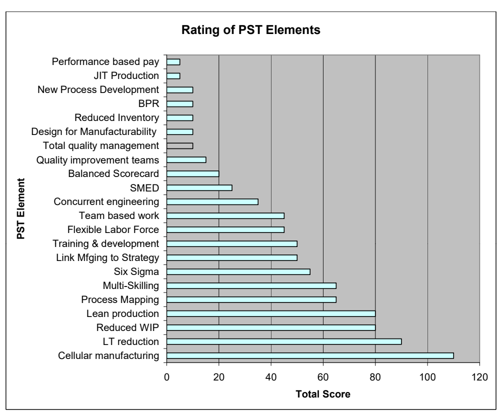
Case Study: Alpha

Summary of PST Elements Selected Across all CRT Roots

Relationship of Root Causes to Best Practices Between Bolden's Taxonomy
Case Study: Alpha
11-Jun-07

Ref #	*PST Element*	*Total Score*
3.C-3	Cellular manufacturing	110
1.C-4	LT reduction	90
1.B-1	Reduced WIP	80
4.B-1	Lean production	80
1.B-3	Process Mapping	65
1.E-2	Multi-Skilling	65
4.D-5	Six Sigma	55
4.B-7	Link Mfging to Strategy	50
1.E-5	Training & development	50
3.B-4	Flexible Labor Force	45
3.E-2	Team based work	45
1.C-2	Concurrent engineering	35
1.C-6	SMED	25
4.B-6	Balanced Scorecard	20
3.A-1	Quality improvement teams	15
4.A-1	Total quality management	10
1.B-4	Design for Manufacturability	10
2.B-1	Reduced Inventory	10
4.C-5	BPR	10
1.D-5	New Process Development	10
1.B-2	JIT Production	5
4.E-3	Performance based pay	5



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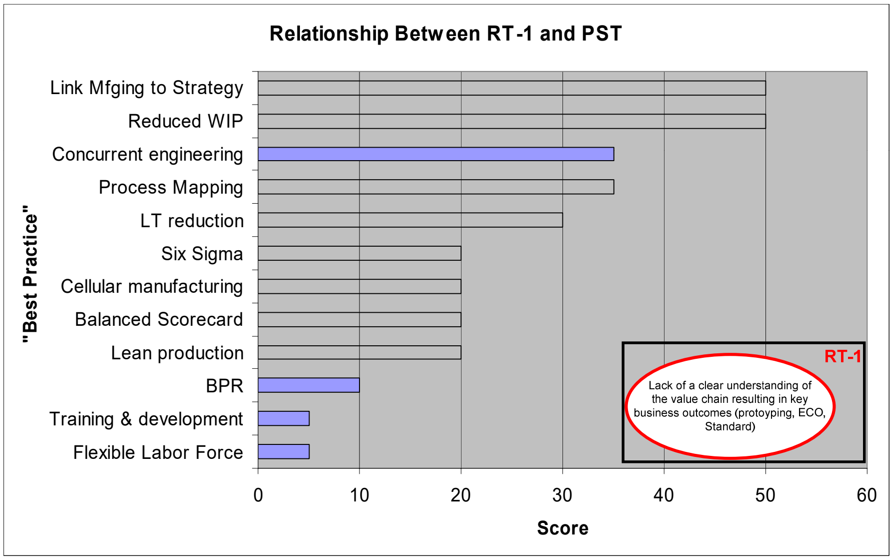
Case Study: Alpha



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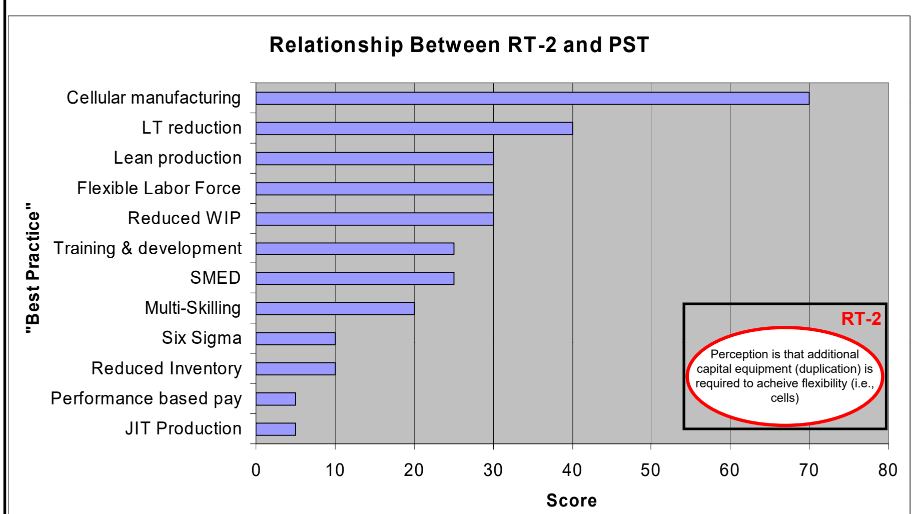
Case Study: Alpha



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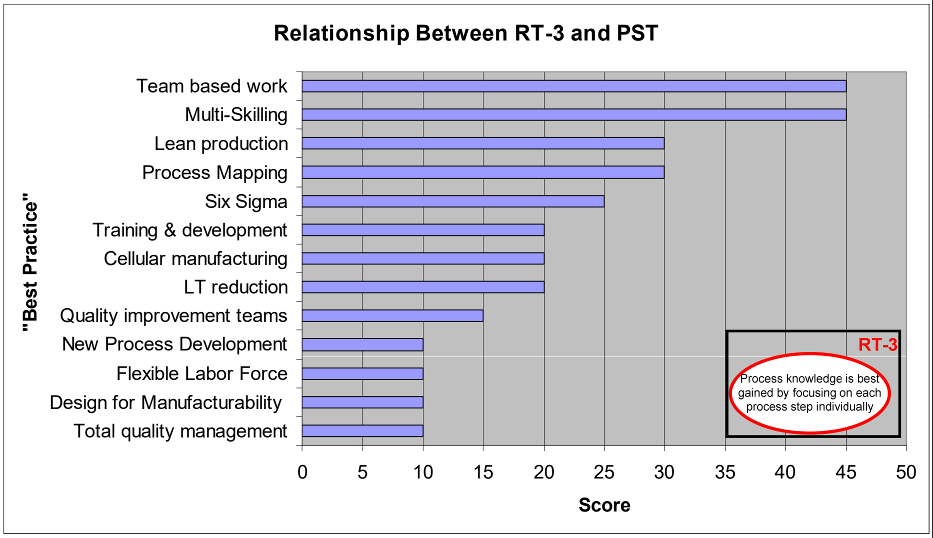
Case Study: Alpha



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Case Study: Alpha

Linking PST Elements to Recommendations

Recommendations

- **Rec_1:** Develop a value stream map for the ECO and prototyping cross functional business processes **(1.B-3). Reengineer the processes both** inside and outside manufacturing so that the company is enabled to handle the changes seamlessly and rapidly **(4.B-1)**. Establish 50% reduction in LT as the major performance measure for guiding improvements **(1.C-4)**. Establish LT as the bridge between manufacturing performance and strategy **(4.B-7)**.
- **Rec_2:** Create separate focus in manufacturing so that regular production and prototypes are not mixed **(3.C-3)** . This may occur due to either physical segregation (i.e., clustering equipment and or workstations) or by time (i.e., shifts). Given the level of demand swings, this should include more aggressive cross training of people **(1.E-2)**.
- **Rec_3:** Establish cross functional management within manufacturing **(3.C-3)** . Leading performance measures are to reduce by 50% LT reduction and WIP **(1.B-1)** . Key enablers **(4.B-1)** appear to be reducing the set-up time on the SMT **(1.C-6)** , size of order releases, and re-arrange equipment to facilitate flow **(3.C-3)**.

Prioritized PST Elements Across all Roots

Ref #	*PST Element*
3.C-3	Cellular manufacturing
1.C-4	LT reduction
1.B-1	Reduced WIP
4.B-1	Lean production
1.B-3	Process Mapping
1.E-2	Multi-Skilling
4.D-5	Six Sigma
4.B-7	Link Mfging to Strategy
1.E-5	Training & development
3.B-4	Flexible Labor Force
3.E-2	Team based work

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Case Study: Alpha

Summary of PST Elements Selected Across all CRT Roots

Relationship of Root Causes to Best Practices Between Bolden's Taxonomy

Case Study: Alpha
11-Jun-07

Ref #	*PST Element*	*Total Score*	*Cumulative %*
3.C-3	**Cellular manufacturing**	**110**	**12%**
1.C-4	**LT reduction**	**90**	**22%**
1.B-1	**Reduced WIP**	**80**	**31%**
4.B-1	**Lean production**	**80**	**40%**
1.B-3	**Process Mapping**	**65**	**48%**
1.E-2	**Multi-Skilling**	**65**	**55%**
4.D-5	**Six Sigma**	**55**	**61%**
4.B-7	**Link Mfging to Strategy**	**50**	**67%**
1.E-5	**Training & development**	**50**	**72%**
3.B-4	**Flexible Labor Force**	**45**	**78%**
3.E-2	**Team based work**	**45**	**83%**
1.C-2	Concurrent engineering	35	87%
1.C-6	SMED	25	89%
4.B-6	Balanced Scorecard	20	92%
3.A-1	Quality improvement teams	15	93%
4.A-1	Total quality management	10	94%
1.B-4	Design for Manufacturability	10	96%
2.B-1	Reduced Inventory	10	97%
4.C-5	BPR	10	98%
1.D-5	New Process Development	10	99%
1.B-2	JIT Production	5	99%
4.E-3	Performance based pay	5	100%
	Total =	890	

"Rule of thumb" - select PST Elements that capture ~80% of multi-vote.

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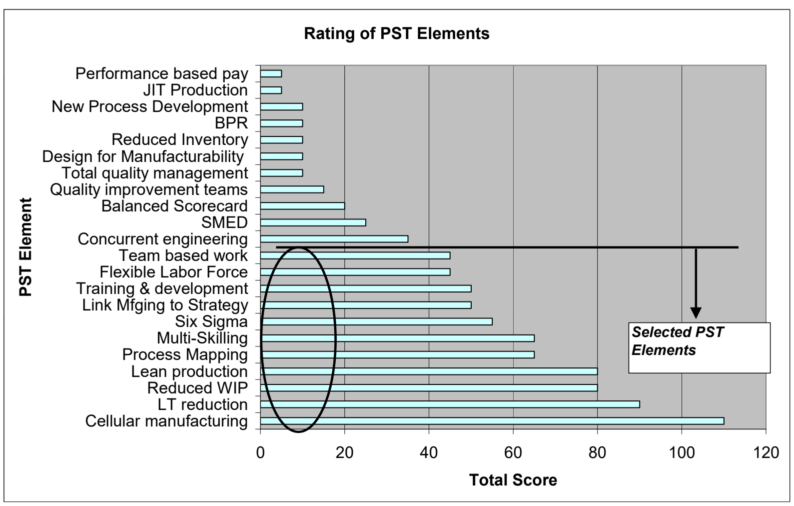
Case Study: Alpha

Summary of PST Elements Selected across all CRT Roots



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Case Study: Alpha

Transformation of UDEs into Recommendations

Undesirable Effects

- **UDE-1:** Not a clearly defined and embraced strategy for how manufacturing should best support a sustained advantage.
- **UDE-2 :** Multiple changes (e.g., changes in product design and changes in design) result in chaos within manufacturing.
- **UDE-3:** Percentage of on-time shipments is running @ 75% which is below customer expectations

Root Causes

RT-1: Lack of clear visibility of the value chain of activities required to support key business outcomes.

RT-2: Perception is that additional capital equipment is needed to achieve flexibility (cells).

RT-3: Process knowledge is best gained by focusing on each step individually.

Selected PST Elements

3.C-3	Cellular manufacturing
1.C-4	LT reduction
1.B-1	Reduced WIP
4.B-1	Lean production
1.B-3	Process Mapping
1.E-2	Multi-Skilling
4.D-5	Six Sigma
4.B-7	Link Mfging to Strategy
1.E-5	Training & development
3.B-4	Flexible Labor Force
3.E-2	Team based work

Recommendations

- **Rec_1:** Develop a value stream map for the ECO and prototyping cross functional business processes. Reengineer the processes both inside and outside manufacturing so that the company is enabled to handle the changes seamlessly and rapidly. Establish 50% reduction in LT as the major performance measure for guiding improvements. Establish LT as the bridge between manufacturing performance and strategy.
- **Rec_2:** Create separate focus in manufacturing so that regular production and prototypes are not mixed. This may occur due to either physical segregation (i.e., clustering equipment and or workstations) or by time (i.e., shifts). Given the level of demand swings, this should include more aggressive cross training of people.
- **Rec_3:** Establish cross functional management within manufacturing. Leading performance measures are to reduce by 50% LT reduction and WIP. Key enablers appear to be reducing the set-up time on the SMT, size of order releases, and re-arrange equipment to facilitate flow.

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Case Study: Alpha

Client Feedback

Recommendation	Effectiveness *"The recommendation, if implemented, would have a substantially positive impact on the manufacturing enterprise."* *Please rate each recommendation on a score of 1-5* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	Implementability *"The recommendation is practical and implementable without spending excessive time and resources."* *Please rate each recommendation on a score of 1-5* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	Overall Score
Rec_1:	4.5	3.5	8
Rec_2:	3	2	5
Rec_3:	5	4	9

General Comments
The process forces logical thinking about big picture issues. These issues tend to have an emotional context which the logical process alleviates. It also serves as a good guidelines for objective discussion. This discussion process has a way of breaking some of the barriers to solving problems being assessed.
Although the process was more time consuming than expected, the result was worth it. It was definitely a learning experience. I regret that I could not be more involved in the details of each stage - time did not permit - but at the conclusion the outcome was fully understandable.

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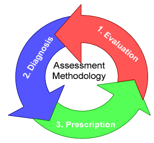
CAVS EXTENSION Center for Advanced Vehicular Systems — Mississippi State University



Case Study - Beta:

Pilot of Taxonomy Based Assessment Methodology (TBAM)

Assessment Team:

Clay Walden, Steve Puryear

August 2-3, 2007

MEP ms Manufacturing Extension Partnership of Mississippi

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Case Study: Beta

Case Study Beta

August 2-3, 2007

Assessors: Clay Walden, Steve Puryear (Mississippi State University, CAVS Extension)

Scope: Focus on the on-site assessment of core functions which support the product manufacturing. On site functions include Human Resources, Accounting, Design, Project Management, Quality, Service, Manufacturing, Purchasing, and Planning.

Client Participants

Plant Manager
HR Manager
Engineering Manager
Quality and Service Manager
Planner
Purchaser
Controller

Products: Power Plant Bus System

Isolated Phase Bus
Rectangular Segregated
Rectangular Non-Segregated

Markets

Sell to Engineering and Contracting Firms
End users are large power plants.

Employees

100 employees
50 Hourly
50 Office

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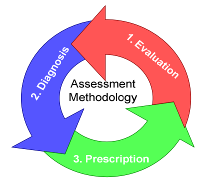
Case Study: Beta



Evaluation Stage

Objective: Identify the client's fit within the Manufacturing Enterprise Taxonomy (MET) and identify Undesirable Effects (UDEs) using the MET based survey instrument.

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Case Study: Beta

General Observations

- Business is characterized by low volume high variety product mix.
- Current business is 80% domestic and 20% international. The international component did not exist a few years ago.
- Product mix is evenly distributed across three major product lines: Integrated Phase Bus, Rectangular Segregated, Rectangular Non-Segregated
- Manufacturing floor is non-union and production is run on currently on 1 shift.
- Highly cyclical business has resulted in swings in employment levels from 50 to 150 across the last several years.
- Corporation: $150M in annual sales and 1100 employees
- Site: ~$24M in sales and 100 employees
- Plant Manager, senior management representative on-site, has been at the plant for only 2 months.
- Orders are custom designed and fabricated.
- Product is somewhat simple but its application in terms of power plant bus systems is somewhat technical
- Engineering staff is predominately non-degreed yet highly experienced and very knowledgeable within the industry

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Case Study: Beta

1.0 Business Environment

1.0 Business Environment *"descriptive"*		Level 1	Score →	Level 5	Evidences
1.1 Competitive Environment	***1.1.1 Intensity of Competition***	Numerous Competitors	3	Few Competitors	*The number of competitors depends upon the product line. In the Isolated Phase Bus (IPB) market - Beta and one other company represents 90% of business. For the Rectangular - Segregated products Beta provides 75% of supply to a single customer, Rectangular - Non-segregated business is split among several different companies.*
3.00	***1.1.2 Stability/Emerging Threats***	Unpredictable Threats	3	Stable/ Few Threats	*Recently experienced severe downturn in their market - 2005. Now is going through a robust period of growth. However, industry is known to be very cyclic. Employment at this plant site has varied between 50 and 150 employees over the years. Biggest overall threat is the overall economy - direct relationship between their business and GDP. As there is a higher demand for power - more power plants are built/updated their is greater demand for their products. Technical threat is if cable buses begin to take the place of bar buses. Cable bus systems are cheaper, but typically only used for long runs. China is an emerging threat - currently an explosion in power plant expansion.*
1.2 Regulatory Environment	***1.2.1 Product Regulations***	Many Regulations	4.5	Few Regulations	*Industry is self regulated - ANSI specs.*
4.50	***1.2.2 Process Regulations***	Many Regulations	4.5	Few Regulations	*Little regulations beyond OSHA*
1.3 Market Conditions	***1.3.1 Seasonality Effect***	Heavy Seasonality	4.5	No Seasonality	*Little to no seasonality is present. There is a slight increase in volume on the rectangular - non segregated during the spring. For the service business the summer is dead due to peak power demands occurring during the summer. However, service work tends to be higher in the spring to prepare for the high demand at the power plants during the summer.*
4.00	***1.3.2 Level of Growth***	No Growth/Shrinking	3.5	High Growth	*Growing at 20% per year. In fact. They are projecting to beat budget by 40%. Overall market is currently experiencing solid growth. This is known to be a highly cyclical business and the industry is currently experiencing strong growth.*

Business Environment ***Average Score*** **3.83**

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Case Study: Beta

2.0 Leadership

2.0 Leadership *"prescriptive"*		Level 1	Score →	Level 5	Evidence
2.1 Strategic Planning & Deployment	***2.1.1 Formal Strategy***	"All things to all"	4.5	Clear: Porter's Generic Strategy	*Two years ago a strategic emphasis was placed on securing jobs with higher profit margins and not bidding on lower margin work (i.e., focusing on industry wide differentiation strategy rather than compete on low cost - Porter's Generic strategy). Beta is particularly strong relative to its competition by its offering in the service, install, repair business. The coupling of initial of production with value add installation and service is a differentiator within the market. The IPB business is particularly sensitive to high quality of service. Frequent visits to the customer and job sites gives them an advantage over competitors. This allows them to win the bid, at times, even when others have lower prices.*
	2.1.2 Deployment	few know / little involvement	3.5	widely understood & clear link to actions	*Reasons for the product standardization emphasis was known and discussed widely.*
2.2 Culture of Empowerment	***2.2.1 Level of Participation***	Restricted Involvement	2.5	High level of Involvement	*Engineering and design experience a high level of employee participation (4) but support functions and the floor have not been as high (2)*
	2.2.2 Effectiveness of Participation	Little evidence of impact	3	Evidence of substantial Impact	*The level of participation among engineering and manufacturing professionals is generally very effective. This group frequently discusses and collaborates and comes to consensus. The manufacturing floor has just started in terms of involvement with Kaizen Events.*

Leadership ***Average Score*** **3.38**

50

Case Study: Beta

3.0 Customer / Market Focus

3.0 Customer / Market Focus *"prescriptive"*		Level 1	Score	Level 5	Evidence
3.1 Translation of Requirements	***3.1.1 Design/Order***	Informal / Unstructured	3.5	intentional and formal	*Due to the project driven aspect of their work the translation of customer requirements on a per order basis has to be very intentional and formal. Two drawing reviews are conducted, design work is contingent upon customer's providing data on obstructions and connection points. CAD work is performed using AutoCAD Inventor.Their appears to be much remaining room for improvement based upon the estimate the comment that two thirds of warranty corrective actions deal with the design function.*
3.00	***3.1.2 Feedback/Reaction***	few know / little involvement	2.5	widely understood & clear link to actions	*No post-mortem review of completed projects unless the project is a problem. Based upon review of warranty data there appears to be significant opportunity to improve the quality of design in order to substantially reduce warranty costs further. However, Design has historically been a bottleneck and source of quality problems - Strong evidence exists that there has been substantial improvement within the last couple of years. Also customers receive a post project survey form, but no evidence that it is routinely reviewed for initiating corrective and preventative actions.*
3.2 Positioning / Value	***3.2.1 Customer Value***	No Clear way to identify (informal)	3	Clearly drives all actions (structured)	*Most important factors are quality, service, and meeting commitments to the customer. There appears to be no technical advantage among competitors in terms of product performance. Service level offered by Beta appears to be superior to the competition and is at times a difference maker in winning jobs even when they are not the lowest price.*
3.00	***3.2.2 Dimensions of Performance***	No Sense of Relative Priorities	3	Clear Understanding	*Sales Manager has stated that reduced lead-time is important for 30% of the jobs being bid. Frequent visits to the job site on service matters sometimes translates into Beta becoming the customers technical advisor prior to the RFQ. Current LT for IPB is 4-6 months (depending on job size). The rectangular products currently have LTs which range from 2-3 months. Under current approach material availability (i.e., Aluminum, Copper) and design and fabrication of structural steel drives LT.*

Customer/ Market Focus ***Average Score*** **3**

51

Case Study: Beta

4.0 Information & Knowledge Management

4.0 Information & Knowledge Management *"descriptive"*		Level 1	Score	Level 5	Evidence
4.1 Access to Information & Knowledge	***4.1.1 Availability of Data to Support Decision Making***	Difficult to obtain & interpret	2	Readily available & understood	*Information and data tends to be very functionalized. Data does not seem to flow easily across departments. Since there are many hand-offs opportunity exists for delays and omissions. Some things are readily available for example hours quoted, project costs, actual vs. budget, … Other things are not so easy to obtain - for example, profitability by product line. Some critical pieces of data related to overall plant capacity are difficult to obtain but are needed to support management decision making. Instead simplistic measures of capacity are available based on estimated man hours and available man-hours. However, plant management is not satisfied with this level of data availability.*
2.50	***4.1.2 Availability of Product/Process Knowledge***	Difficult to obtain & interpret	3	Readily available & understood	*Welding quality manual exists, and prints are issued per discrete jobs. Test results. Prints, and all related documents are all available in a directory structure on the server. Opportunity exists for a better capture of design theory knowledge for teaching internally and dealing with customers. They have recently formed a design technical committee and held in-house training.*
4.2 Supportive of Improvement Efforts	***4.2.1 Operations Data/Information***	Difficult to obtain & interpret	2	Readily available & understood	*Data regarding supplier performance from both a quality and due date performance are not readily available. Data regarding plant due date performance is suspect and does not effectively drive improvement efforts. Data and information regarding capacity is at such a gross level that it is not sufficient to drive improvements. On the positive side traditional quality measures like scrap and warranty costs are measured and tracked and appear to effectively support documented improvements in those metrics.*
2.00	***4.2.2 Financial Data/Information***	Difficult to obtain & interpret	2	Readily available & understood	*Profitability per product line is not very clear from the financial reports. They have just started to focus on an overall breakdown of traditional cost measures like overhead, utility, material costs, …*

Information & Knowledge Management ***Average Score*** **2.25**

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5.0 Human Resources

5.0 Human Resources *"prescriptive"*		***Level 1***	***Score***	***Level 5***	***Evidence***
5.1 Maturity in Teaming	***5.1.1 Level of Team Success***	Limited / Informal	3.5	Frequent / Formal	*Project work drives "interconnectedness" - frequent working meetings, collaboration, and group decision making. The most recent success that the design team worked on was the effort to increase product standardization. Other support activities are not as tightly linked. Team success on the floor is still early, but they have experienced success of recent 5S kaizen events conducted on the rectangular products. A schedule of kaizen events has been developed so that the entire plant will be hit within the next year.*
3.50	***5.1.2 Qualities Considered in Hiring/Promotion***	Task Skills dominate	3.5	Balance Between Task & Teaming Skills	*Regularly look for teaming qualities during interview. Also teaming is explicitly considered during the annual review process.*
5.2 Employee Skill Level	***5.2.1 Level of Cross Functional Mastery***	Primarily within function	2.5	Mastery of a variety of skills is widely deployed	*The more senior people tend to be experienced in other functions. This is due to the cyclical nature of the business and the associated expansion and contraction of the workforce. Also more exposure to other functions has occurred has a result of participation on ISO 9000 internal audits. People's behavior's tend to be more functionalized than their understanding. This is more true for the office than for the plant.*
2.50	***5.2.2 Mastery of Key Skills***	Not identified and/or inexperience	2.5	Identified & clear strengths exist	*In engineering the key skills have not been identified as clearly as they have been on the plant floor.*

Human Resources ***Average Score*** **3**

53

6.0 Development of Products and Processes

6.0 Development of Products & Processes *"prescriptive"*		***Level 1***	***Score***	***Level 5***	***Evidence***
6.1 Product Development	***6.1.1 New Product Development Lead-Time***	Inferior to Competition	3.5	Superior to Competition	*In this type of business that focuses on "custom engineered solutions" there is a difficult yet very important distinction between the engineering required to define the order for fabrication and the more fundamental development of new core products. Also a strategic initiative was started in order to bring some level of standardization by defining product standards. Historically they have treated each order as if it were totally unique. Their work on product standardization has just started to bring higher efficiencies to design and production. It appears as if there is even more opportunity in terms of modular design concepts and parametric design.* *Another recent example of product design has been that they have changed the insulators and closure designs. The early results from their efforts at product standardization appear to be positive.*
3.50	***6.1.2 Effectiveness of Product Development***	Inferior to Competition	3.5	Superior to Competition	*Service retrofit tends to be superior to the competition. Produced products are roughly on par with their competition.*
6.2 Process Development	***6.2.1 New Process Development Lead-Time***	Inferior to Competition	4	Superior to Competition	*Example of the recent effectiveness of the 5S kaizen events. They are much more flexible to make rapid changes than is there competition. The competition tends to include processes with more capital and fixed automation. Beta has been somewhat slow to adapt automated solutions for at least a couple of reasons. One is the cyclical nature of the business and the associated uncertainty in demand. It is very important to Beta to preserve flexibility in the design of the production process. The concept of linearity (i.e., ability to add or take away labor using the same line layout) may be important to Beta has they revamp the shop floor through a series of 5S events. Lack of a heavy amount of fixed automation means that they are very flexible to change the floor layout rapidly in response to improvement ideas or to changes in customer demand between products.*
4.00	***6.2.2 Effectiveness of New Process Development***	Inferior to Competition	4	Superior to Competition	*Competition has invested heavier in fixed automation - which is not as flexible.*

Development of Products & Processes ***Average Score*** **3.75**

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Case Study: Beta

7.0 Product and Process Characterization

7.0 Product & Process Characterization "descriptive"		Score: Level 1		→ Level 5	Evidence
7.1 Product Characterization 3.00	7.1.1 Product Lifetime	Short	4	Long	30-40 years is not uncommon
	7.1.2 Product Volume	Low	2	High	
	7.1.3 Product Complexity	Low	2	High	The complexity regarding product design was many years ago when the basic designs were first established. Contract design work essentially parameterizes basic design.
	7.1.4 Product Variety	Low	4	High	Lots of product variety in terms of dimension requirements, amperage, type of insulators, bends/angles dictated by each unique job.
7.2 Process Characterization 3.17	7.2.1 Process Capacity	Excess	4	Minimal	Currently loading at close to 100% - however if capacity can be opened up they could probably sell more during the current expanding market conditions.
	7.2.2 Layout of Processes	Functional	2	Cellular	
	7.2.3 Process Integration	Low	3.5	High	Some opportunity to cut to shape in-house.
7.3 Product-Process Characterization 4.00	7.3.1 Goldratt's VAT	Unclear Fit	4	Clear Fit	Mostly like A plant
	7.3.2 Hayes-Wheelwright Matrix	Unclear Fit	4	Clear Fit	Disconnected Line (Batch) - Multiple products low volume

Product & Process Characterization — Average Score: 3.28

55

Case Study: Beta

8.0 Management of Extended Enterprise

8.0 Management of Extended Enterprise "prescriptive"		Score: Level 1		→ Level 5	Evidence
8.1 Supply Chain Management 2.25	8.1.1 Product Requirements	Unclear	3	Clear	Physical product requirements are well defined. Since much of the material purchases are initiated by project there may be an opportunity to reduce the number of purchased part numbers by buying a more raw level and cutting to size in house. It was noted that 75% of items purchased are driven by products and 25% are based upon forecasted usage. However, 95% of the dollar value of items are driven by specific projects.
	8.1.2 Ordering & Inventory Requirements	Unclear	1.5	Clear	Vendor performance to due dates is not clearly established, measured, and reported on. It is not treated as a performance measure to be improved. It is not uncommon for both dates and quantities to change. It was stated that suppliers ship 90% on-time - no data provided to substantiate this claim. Sometimes changes are made in the orders driven from a change in the customer's requirements. Change orders are processed. Approximately $1.5M is the value of raw materials, $1.5M in WIP, and FG's is virtually negligible. Inventory Turns are at 6 times per year. The currently the LT of key components are as follows AL plate - 14 weeks, Copper - 7 weeks, Insulators 3 days (true for 1 insulator which is 90% of volume), enclosures - 2-3 days (stocked locally). Structural Steel is a problem for 8 out of 10 jobs. Structural steel however must wait for all customer changes to be completed, internal design package created, outside engineering analysis, Beta to order, Steel vendor to build, Galvanizer, back to Beta, send to customer. Thus steel has many handoffs which start late in the cycle but must be the first to arrive at the job site. Each project is scheduled using MS Project.
8.2 Distribution Chain Management 2.50	8.2.1 Finished Goods Management	Unclear	3	Clear	Very little FGs are kept. Customer's require the structural steel to ship first and the bus work second.
	8.2.2 Order Fulfillment Management	Not meeting Customer Desires	2	Regularly Meeting Customer Desires	Current due date performance is ~ 60% as measured and documented. However, this metric is of questionable value due to fuzziness regarding customer due dates . it is not clear what is Beta's true ability to meet customer actual desired due dates. The original due date established at the time of the PO was set long ago. Frequently the customers actually want a later due date (note bus work installation occurs later in the construction time line) and communicate this desire. However, if the due date on the PO is not changed (which often is not done due to administrative trouble) then Beta is measured against the original due date (which is no longer relevant). Generally customer are expecting LT's commensurate with the general LTs associated with key metals - Aluminum and Copper. Recently 8 out of 10 jobs being were in doubt regarding ability to meet customer due date requirements. Customer changes continue as the project progresses. No mention was made of a change order process where premiums are charged in order to meet the customer changes. Perhaps a more common problem is the case where customer's are late sending key information needed, which in turn causes late design work, and can result in a late delivery. At the conclusion of the project it is at times not a clear agreement with the customer regarding whose responsibility it is for failure to deliver on time. At times warranties are used to reach a compromise.

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Management of Extended Enterprise — Average Score: 2.38

Case Study: Beta

9.0 Approach to Continuous Improvement

9.0 Approach to Continuous Improvement *"Prescriptive"*		***Level 1***	***Score*** →	***Level 5***	***Evidence***
9.1 Performance Measures	***9.1.1 Strategic Alignment of Operational Measures***	fuzzy connection	2	clearly articulated	*On the operations side a strategic emphasis was placed on reducing the cost of poor quality. Missing are performance measures related to LT reduction and capacity increase.*
	9.1.2 Balanced & Multi-dimensional	single dimension (e.g., cost)	2.5	multi-dimensional & balanced	*Current set of measures has been mostly defined by Beta's quality system (Cost of Poor Quality, On Time Delivery, Corrective Actions, Customer Complaints, Internal Audits). Another metric reviewed is job cost relative to budget. However this was not seen to be graphed and tracked overall. Clearly their is management review on a case by case basis. Missing are performance measures related to LT reduction and capacity increase. Several financial measures have just now started being tracked: material costs, OVH costs, ...*
9.2 Process Focus	***9.2.1 Identification of Key Processes***	unsupported	2.5	documented & communicated	*It was not clear that which of the manufacturing processes were key for tracking certain overall performance metrics. For example, the long lead-time due to structural steel design and fabrication while recognized by those working at a functional level has not been elevated and focused on in terms of fundamental improvement.*
	9.2.2 Constraints	unknown	1.5	known & managed	*No data to pinpoint. Some thought that the constraint I powder coat epoxy (located off site).*
	9.2.3 Emphasis on Variability & CT Reduction	none	2	drives action	*efforts at product standardization is an early attempt. Subtanial reduction of scrap reduction occurred but not obvious connection was made to overall lead-time improvements.*
9.3 Use of World Class Practices	***9.3.1 Continuous Improvement Approach***	informal	2.5	formal & intentional	*Just started 5S kaizens events. Plans to hire a continuous improvement manager within the next couple of weeks.*
	9.3.2 Effectiveness	unclear	3	clear & documented	*Some indication of strong improvement in scrap (i.e., from $30K per month to $500/month) and warranty claims over the last several years. No evidence of systematic waste elimination within the plant.*
9.4 Quality System	***9.4.1 Formal System***	Informal & unstructured	4	formal & registered	*Registered to ISO 9001*
	9.4.2 Effectiveness	conformance driven	2.5	performance driven	*Some evidence of strong improvement in cost of poor quality, warranty, scrap. Biggest opportunity to drive warranty costs down is to reduce design errors - estimated 75% of warranty causes reside within the design function.*

Approach to Continuous Improvement ***Average Score*** **2.50**

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Case Study: Beta

10.0 Enterprise Financial Health

10.0 Enterprise Financial Health *"Descriptive"*		***Level 1***	***Score*** →	***Level 5***	***Evidence***
10.1 Ability to Invest in Assets	***10.1.1 Capital Availability***	not possible / severely restricted	3.5	Adequate	*Capital is available to invest from a corporate standpoint as long as the company is having a good profit year. Capital investments are tied to gaining increases in sales. Much more difficult to get investment for sustained cost savings over a period of time. This is due to the cyclic nature of the business. which shortens the time horizon for return on investment. The corporate tendency is to not put a lot of assets into the plant that can't be paid back during a downturn (i.e., cyclic business)*
10.2 Liquidity	***10.2.1 Cash Flow***	severely restricted	4	sufficient	*Not an issue or a barrier for operations*

Enterprise Financial Health ***Average Score*** **3.75**

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Case Study: Beta

Summary of MET Survey Scoring

Category	Sub-category	Item	Score	Average for Category	Average for Taxon
1.0 Business Environment					
	1.1 Competitive Environment	1.1.1 Intensity of Competition	*3*	3.00	3.83
		1.2.1 Stability/Emerging Threats	*3*		
	1.2 Regulatory Environment	1.2.1 Product Regulations:	*4.5*	4.50	
		1.2.2 Process Regulations:	*4.5*		
	1.3 Market Conditions	1.3.1 Seasonality Effect	*4.5*	4.00	
		1.3.2 Level of Growth	*3.5*		
2.0 Leadership					
	2.1 Strategic Planning & Deployment	2.1.1 Formal Strategy	*4.5*	4.00	3.38
		2.1.2 Strategy Deployment	*3.5*		
	2.2 Culture of Empowerment	2.2.1 Level of Participation	*2.5*	2.75	
		2.2.2 Effectiveness of Participation	*3*		
3.0 Customer / Market Focus					
	3.1 Translation of Requirements	3.1.1 Design/Order	*3.5*	3.00	3.00
		3.1.2 Feedback/Reaction	*2.5*		
	3.2 Positioning / Value	3.2.1 Customer Value	*3*	3.00	
		3.2.2 Dimensions of Performance	*3*		
4.0 Information System & Knowledge Management					
	4.1 Access to Information & Knowledge	4.1.1 Availability to Data/Information to Support Decision Making	*2*	2.50	2.25
		4.1.2 Availability of Product/Process Knowledge	*3*		
	4.2 Supportive of Improvement Efforts	4.2.1 Operations Data/Information	*2*	2.00	
		4.2.2 Financial Data/Information	*2*		
5.0 Human Resources					
	5.1 Maturity in Teaming	5.1.1 Level of Team Successes	*3.5*	3.50	3.00
		5.1.2 Team Qualities Considered Strongly in Hiring/Promotion	*3.5*		
	5.2 Employee Skill Level	5.2.1 Cross Functional Encourgement	*2.5*	2.50	
		5.2.2 Opportunties for Developing Additional Skills	*2.5*		
6.0 Development of Products & Processes					
	6.1 Product Development	6.1.1 New Product Development Time	*3.5*	3.50	3.75
		6.1.2 Effectiveness of New Products Relative to Opportunity	*3.5*		
	6.2 Process Development	6.2.1 New Process Development Time	*4*	4.00	
		6.2.2 Effectiveness of New Processes Relative to Opportunity	*4*		
7.0 Product & Process Characterization					
	7.1 Product Characterization	7.1.1 Product Lifetime	*4*	3.00	3.28
		7.1.2 Product Volume	*2*		
		7.1.3 Product Complexity	*2*		
		7.1.4 Product Variety	*4*		
	7.2 Process Characterization	7.2.1 Process Capacity	*4*	3.17	
		7.2.2 Layout of Processes	*2*		
		7.2.3 Process Integration	*3.5*		
	7.3 Product-Process Characterization	7.3.1 Goldratt's VAT Logical Product-Process	*4*	4.00	
		7.3.2 Hayes-Wheelwright Matrix	*4*		
8.0 Management of Extended Enterprise					
	8.1 Supply Chain Management	8.1.1 Management of Requirements (Product & Ordering)	*3*	2.25	2.38
		8.1.2 Management of Incoming Inventory	*1.5*		
	8.2 Distribution Chain Management	8.2.1 Management of Finished Goods Inventory	*3*	2.50	
		8.2.2 Management of Order Fullfillment	*2*		
9.0 Approach to Continuous Improvement					
	9.1 Performance Measures	9.1.1 Strategic Alignment of Operational Measures	*2*	2.25	2.50
		9.1.2 Balanced & Multi-dimensional	*2.5*		
	9.2 Process Focus	9.2.1 Key Process Identification	*2.5*	2.00	
		9.2.2 Constraints	*1.5*		
		9.2.3 Emphasis on Variability & CT Reduction	*2*		
	9.3 Use of Specific World Class Practices	9.3.1 Formal Adoption of a CI Approach	*2.5*	2.75	
		9.3.2 Demonstration of Effectiveness	*3*		
	9.4 Quality System	9.4.1 Formal System	*4*	3.25	
		9.4.2 Demonstration of Effectiveness	*2.5*		
10.0 Enterprise Financial Health					
	10.1 Capital Availability	10.1.1 Capital Availability	*3.5*	3.50	3.75
	10.2 Liquidity	10.2.1 Cash Flow	*4*	4.00	

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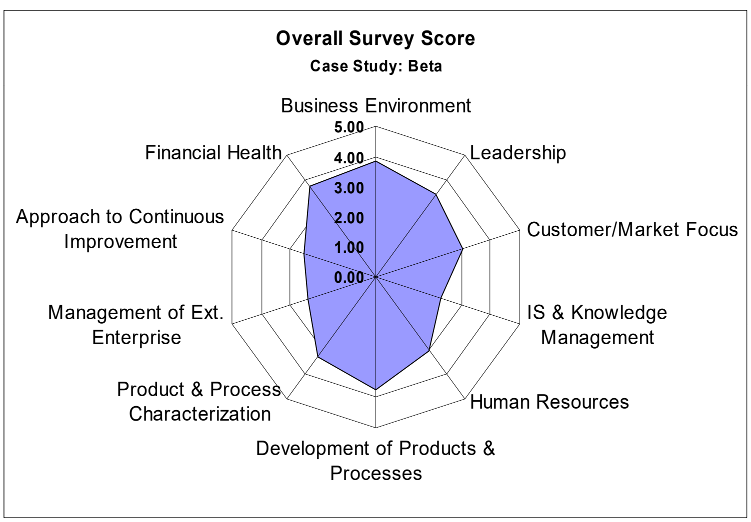
Case Study: Beta

MET Scoring Across Major Attributes



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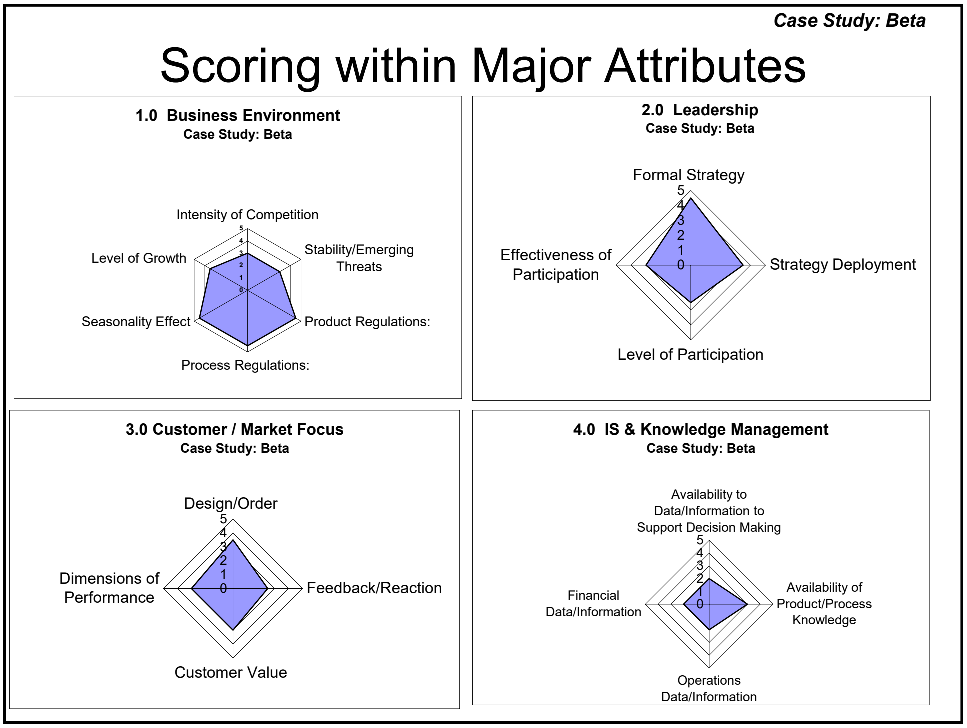
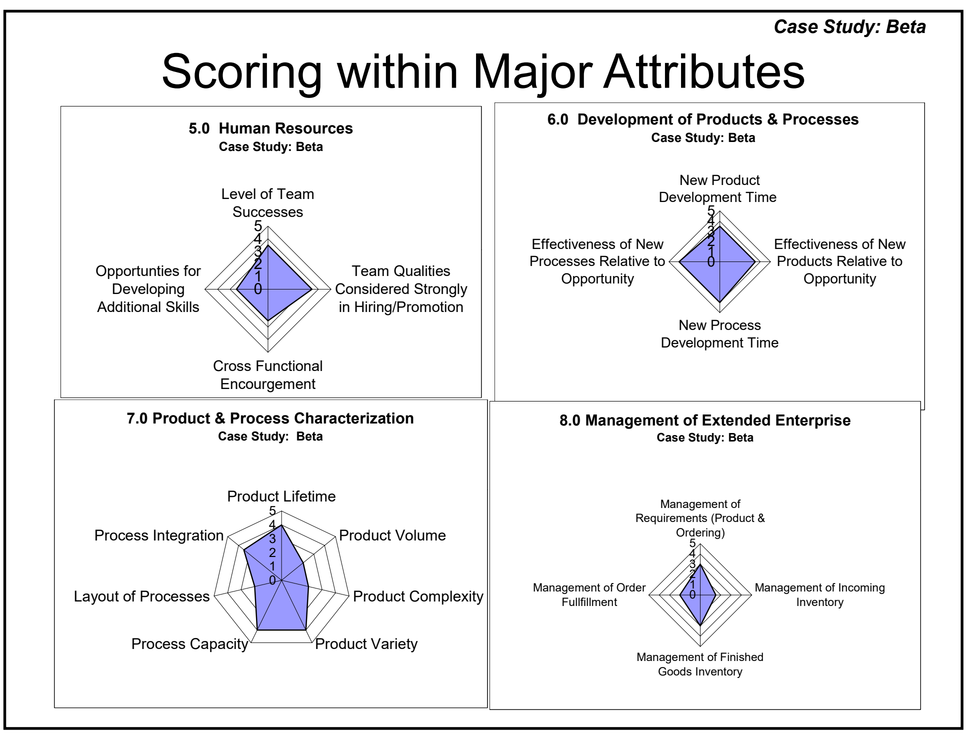

Case Study: Beta
Scoring within Major Attributes
1.0 Business Environment
Case Study: Beta
Intensity of Competition
Stability/Emerging Threats
Product Regulations:
Process Regulations:
Seasonality Effect
Level of Growth
2.0 Leadership
Case Study: Beta
Formal Strategy
Strategy Deployment
Level of Participation
Effectiveness of Participation
3.0 Customer / Market Focus
Case Study: Beta
Design/Order
Feedback/Reaction
Customer Value
Dimensions of Performance
4.0 IS & Knowledge Management
Case Study: Beta
Availability to Data/Information to Support Decision Making
Availability of Product/Process Knowledge
Operations Data/Information
Financial Data/Information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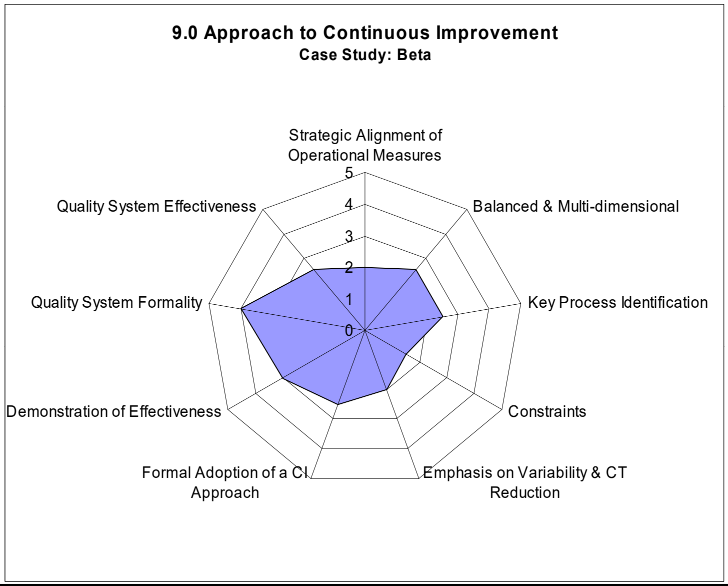
Scoring within Major Attributes
5.0 Human Resources
Case Study: Beta
Level of Team Successes
Team Qualities Considered Strongly in Hiring/Promotion
Cross Functional Encourgement
Opportunties for Developing Additional Skills
6.0 Development of Products & Processes
Case Study: Beta
New Product Development Time
Effectiveness of New Products Relative to Opportunity
New Process Development Time
Effectiveness of New Processes Relative to Opportunity
7.0 Product & Process Characterization
Case Study: Beta
Product Lifetime
Product Volume
Product Complexity
Product Variety
Process Capacity
Layout of Processes
Process Integration
8.0 Management of Extended Enterprise
Case Study: Beta
Management of Requirements (Product & Ordering)
Management of Incoming Inventory
Management of Finished Goods Inventory
Management of Order Fullfillment

Case Study: Beta

Scoring within Major Attributes



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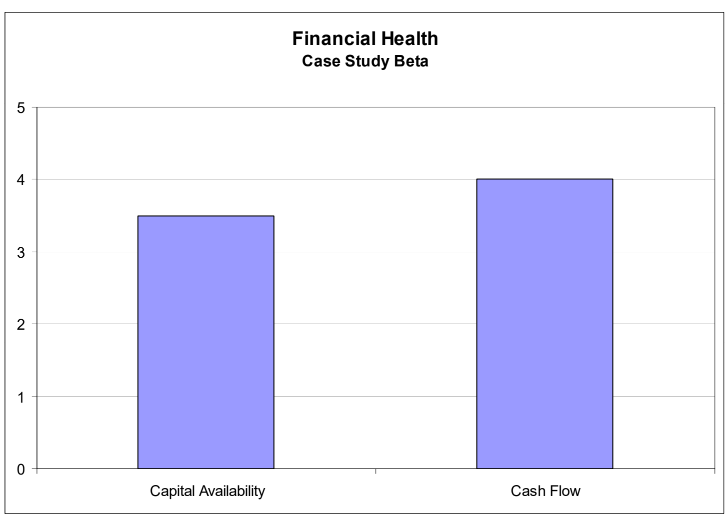
Case Study: Beta

Scoring within Major Attributes



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Case Study: Beta

Prioritization of UDEs

Prioritization of UDEs Identified During the MET Survey			***Case: Beta***
	UDE	**Overall**	**Cumulative Percentage**
1	***Steel delivery is late***	***30***	***30%***
2	***Standard LT's are limiting additional volume with higher margins***	***20***	***50%***
3	***Capacity is not managed as a performance measure***	***20***	***70%***
4	Information resides within silo's and does not flow easily across functions.	10	***80%***
5	Measurement of "On Time" shipments to customers is not reliable.	5	***85%***
6	Measurement of Vendor "on-time" performance is not clear.	5	***90%***
7	Inventory dollar value is "high" (i.e., turns are "low")	5	***95%***
8	Every job is treated as "new"	5	***100%***
9	Functional interests drives behaviors more than cross functional needs.	0	***100%***
	Total	100	

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Case Study: Beta

UDEs Selected for Probing During Diagnosis Phase

Highest Priority UDEs for Use in CRT Construction
UDE-1 Steel delivery is late
UDE-2 Standard LT's are limiting additional volume with higher margins
UDE-3 Capacity is not managed as a performance measure

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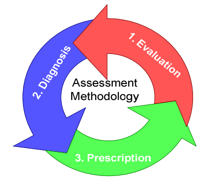
Case Study: Beta



Diagnosis Stage

Objective: Translate Undesirable Effects (UDEs) into Root Cause(s) through the use of Current Reality Tree.

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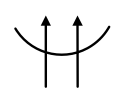
Current Reality Tree: Legend

Undesirable Effect

Cause and Effect Linkage

AND Condition



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Root Cause

Fact of Life

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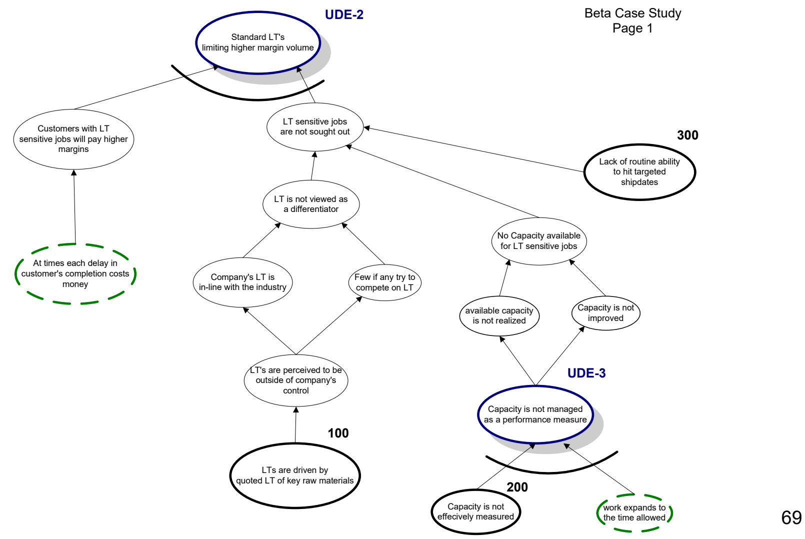
Beta CRT – Page 1



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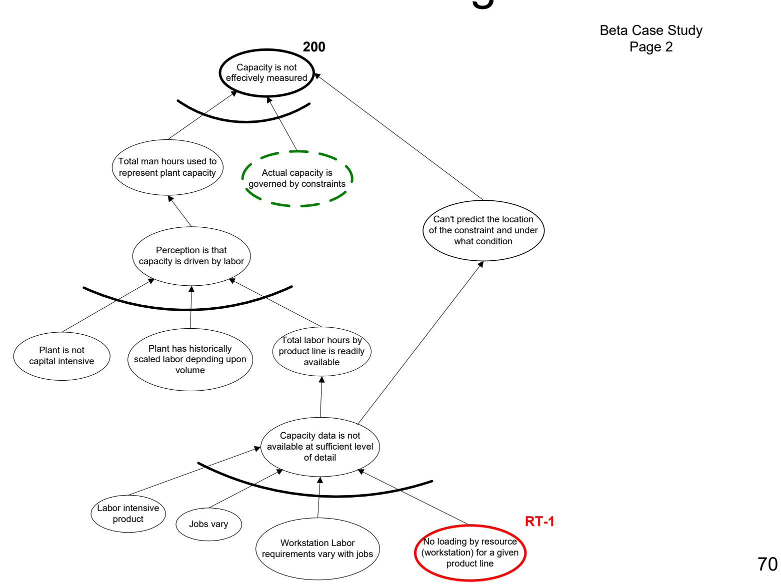
Beta CRT – Page 2



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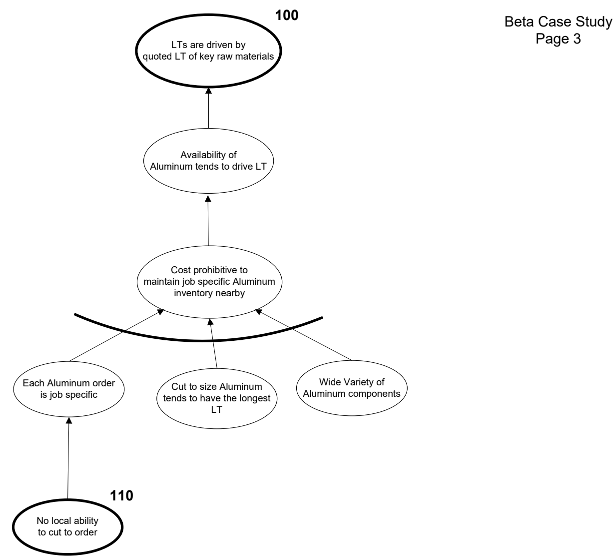
Beta CRT – Page 3



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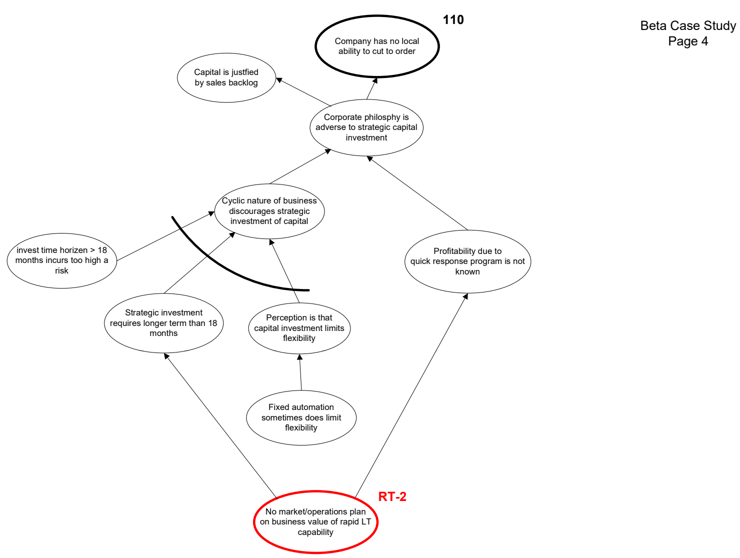
Beta CRT – Page 4



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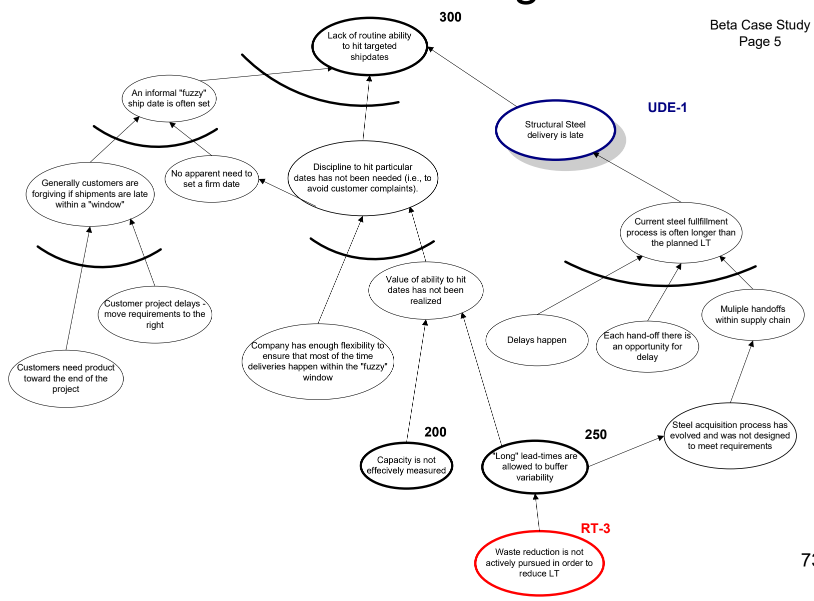
Beta CRT – Page 5



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Case Study: Beta

Case Beta: Summary UDEs and Root Causes

UDEs	Root Causes
• **UDE-1:**. Structural steel delivery is late. • **UDE-2 :** Standard Lead-Time's are limiting higher margin volume • **UDE-3:** Capacity is not managed as a performance measure	• **RT-1:** No loading by resource (i.e., workstation) for a given product line. • **RT-2:** No market operations plan on business value of the development of a rapid lead-time capability. • **RT-3:** Waste reduction is not actively pursued in order to reduce lead-time.

Note: There is not a one-to-one relationship between the three UDEs and the three root causes. The relationships are defined by the CRT.

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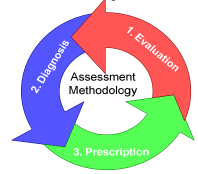
Case Study: Beta



Prescription Stage

Objective: *develop a set of recommendations which target elimination of root causes identified during diagnosis. The recommendations are developed guided by appropriate elements selected from within the PST*

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Case Study: Beta

Production System Taxonomy (PST) – Bolden's Modified Taxonomy				Root Causes from the Current Reality Tree												
				RT-1 No loading by resource (workstation for a given product line				RT-2 No Market/Operations plan on business value of rapid LT capability				RT-3 LT is not seen as a function of the waste in the process				Element Total
Problem Domain	Strategic Emphasis	Reference Number	"Best Practice"	CW	SP	SMR	Sum of RT-1	CW	SP	SMR	Sum of RT-2	CW	SP	SMR	Sum of RT-3	
Design and Production	Improved Quality	1.A-1	Quality Standards				0				0				0	0
		1.A-2	SPC				0				0				0	0
		1.A-3	TPM			5	5				0			5	5	10
		1.A-4	QFD				0			5	5				0	5
		1.A-5	Poke-Yoke				0				0				0	0
Inventory and Stock		2.A-1	Supply Chain Partnering				0	10	10	20	40				0	40
		2.A-2	Customer Feedback				0			5	5				0	5
		2.A-3	Conformance Checks				0				0				0	0
Work Organization		3.A-1	Quality improvement teams	10	10		20				0	5	5	5	15	35
		3.A-2	Operator responsibility				0				0				0	0
		3.A-3	Quality feedback to operators				0				0				0	0
		3.A-4	Quality training				0				0				0	0
		3.A-5	Ergonomic design				0				0				0	0
Wider Organization		4.A-1	Total quality management				0				0				0	0
		4.A-2	Quality awards				0				0				0	0
		4.A-3	Internationally Competitive Benchmarking for Quality				0				0				0	0
Design and Production	Reduced Cost	1.B-1	Reduced WIP				0				0	10	10	5	25	25
		1.B-2	JIT Production	10	10	5	25				0	10	10	5	25	50
		1.B-3	Process Mapping	10	10	10	30	5	5	5	15	5	5	5	15	60
	0	1.B-4	Design for Manufacturability								0			5	5	5
		1.B-5	Re-usability				0				0				0	0
		1.B-6	Value Engineering				0			5	5			5	5	10
Inventory and Stock		2.B-1	Reduced Inventory				0				0				0	0
		2.B-2	Single Sourcing				0				0				0	0
		2.B-3	JIT Inventory Control	10	10	10	30	10	10		20	5	5		10	60
		2.B-4	Forecasting			15	15				0			5	5	20
		2.B-5	Logistics Management			5	5				0			5	5	10
Work Organization		3.B-1	Downsizing				0				0				0	0
		3.B-2	De-layering				0				0				0	0
		3.B-3	Outsourcing				0				0				0	0
		3.B-4	Flexible Labor Force				0				0				0	0
Wider Organization		4.B-1	Lean production				0		10		10	10	10	10	30	40
		4.B-2	Cost management				0				0				0	0
		4.B-3	Financial performance				0				0				0	0
		4.B-4	Time based management				0	10			10	20	20		40	50
		4.B-5	Benchmarking: costs				0				0				0	0
		4.B-6	Balanced Scorecard				0				0				0	0
		4.B-7	Link Mfging to Strategy	20	20		40	15	15	5	35				0	75
Design and Production	Responsiveness to Customer	1.C-1	Rapid prototyping				0				0				0	0
		1.C-2	Concurrent engineering				0				0				0	0
		1.C-3	Customer involvement in design				0				0				0	0
		1.C-4	LT reduction	15	15		30	10	10	5	25	10	10	10	30	85
		1.C-5	Agile manufacturing				0				0			10	10	10
		1.C-6	SMED				0				0				0	0
Inventory and Stock		2.C-1	Predicting customer requirements			5	5				0			5	5	10
		2.C-2	Maintaining stock levels			5	5	5	5		10				0	15
Work Organization		3.C-1	Flexible work organization				0				0				0	0
		3.C-2	After sales support				0				0				0	0
		3.C-3	Cellular manufacturing	5	5	5	15	10	10		20	5	5	5	15	50
Wider Organization		4.C-1	Customer Focus				0				0				0	0
		4.C-2	Market research				0			5	5				0	5
		4.C-3	Customer surveys				0	5	5	5	15				0	15
		4.C-4	Bench. for customer Responsiveness				0			5	5				0	5
		4.C-5	BPR				0			5	5				0	5
Design and Production	Improved Technology	1.D-1	CAPP				0				0				0	0
		1.D-2	CIM				0				0				0	0
		1.D-3	Automation				0				0			5	5	5
		1.D-4	CAD & engineering				0	5	5	15	25			5	5	30
		1.D 5	New Process Development				0				0			5	5	5
Inventory and Stock		2.D-1	Automated storage & retrieval systems				0				0				0	0
		2.D-2	EDI				0				0				0	0
Work Organization		3.D-1	FMS				0				0				0	0
		3.D-2	Group Technology				0				0				0	0
		3.D-3	Computer co-operative work				0				0				0	0
		3.D-4	MRP/ERP	20	20	25	65				0				0	65
Wider Organization		4.D-1	Information Technology strategy				0				0				0	0
		4.D-2	Decision Support Sys.				0				0				0	0
		4.D-3	Technology Benchmarking				0			10	10				0	10
		4.D-4	Environmental Compatibility				0				0				0	0
		4.D-5	Six Sigma				0				0				0	0
Design and Production	Employee Development	1.E-1	Job Rotation				0				0				0	0
		1.E-2	Multi-Skilling				0				0				0	0
		1.E-3	Psychomterics				0				0				0	0
		1.E-4	Appraisal				0				0				0	0
		1.E-5	Training & development			5	5				0				0	5
		1.E-6	Suggestion schemes				0				0				0	0
		1.E-7	Attitude surveys				0				0				0	0
		1.E-8	Staff/Management Rotation				0				0				0	0
		1.E-9	Safety management				0				0				0	0
Inventory and Stock		2.E-1	Product team (purchasing and distribution)				0				0				0	0
Work Organization		3.E-1	Reduce Status Barriers				0				0				0	0
		3.E-2	Team based work				0				0				0	0
		3.E-3	Job Enrichment				0				0				0	0
		3.E-4	Boundary Management			5	5	10	10		20				0	25
Wider Organization		4.E-1	HRM strategy				0				0				0	0
		4.E-2	Empowerment				0				0	10	10		20	20
		4.E-3	Performance based pay				0				0				0	0
		4.E-4	Culture change				0	5	5	5	15	10	10		20	35
		4.E-5	Learning climate				0				0				0	0
		4.E-6	Investors in people				0				0				0	0
		4.E-7	Benchmark people effectiveness				0				0				0	0
			Total	100	100	100	300	100	100	100	300	100	100	100	300	

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Case Study: Beta

Ref #	PST Element	Total Score (overall)	Cumulative %
1.C-4	LT reduction	85	9%
4.B-7	Link Mfging to Strategy	75	18%
3.D-4	MRP/ERP	65	25%
1.B-3	Process Mapping	60	32%
2.B-3	JIT Inventory Control	60	38%
1.B-2	JIT Production	50	44%
4.B-4	Time based management	50	49%
3.C-3	Cellular manufacturing	50	55%
2.A-1	Supply Chain Partnering	40	59%
4.B-1	Lean production	40	64%
3.A-1	Quality improvement teams	35	68%
4.E-4	Culture change	35	72%
1.D-4	CAD & engineering	30	75%
1.B-1	Reduced WIP	25	78%
3.E-4	Boundary Management	25	81%
2.B-4	Forecasting	20	83%
4.E-2	Empowerment	20	85%
2.C-2	Maintaining stock levels	15	87%
4.C-3	Customer surveys	15	88%
1.A-3	TPM	10	89%
1.B-6	Value Engineering	10	91%
2.B-5	Logistics Management	10	92%
1.C-5	Agile manufacturing	10	93%
2.C-1	Predicting customer requirements	10	94%
4.D-3	Technology Benchmarking	10	95%
1.A-4	QFD	5	96%
2.A-2	Customer Feedback	5	96%
1.B-4	Design for Manufacturability	5	97%
4.C-2	Market research	5	97%
4.C-4	Bench. for customer Responsiveness	5	98%
4.C-5	BPR	5	98%
1.D-3	Automation	5	99%
1.D-5	New Process Development	5	99%
1.E-5	Training & development	5	100%
	Total	***900***	

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Case Study: Beta

Scoring by Root #1

RT-1 No loading by resource (workstation for a given product line)

Ref #	PST Element	Score	Cumulative %
3.D-4	MRP/ERP	65	22%
4.B-7	Link Mfging to Strategy	40	35%
1.B-3	Process Mapping	30	45%
2.B-3	JIT Inventory Control	30	55%
1.C-4	LT reduction	30	65%
1.B-2	JIT Production	25	73%
3.A-1	Quality improvement teams	20	80%
2.B-4	Forecasting	15	85%
3.C-3	Cellular manufacturing	15	90%
1.A-3	TPM	5	92%
2.B-5	Logistics Management	5	93%
2.C-1	Predicting customer requirements	5	95%
2.C-2	Maintaining stock levels	5	97%
1.E-5	Training & development	5	98%
3.E-4	Boundary Management	5	100%
	Total	***300***	

Scoring by Root #2

RT-2 No Market/Operations plan on business value of rapid LT capability

Ref #	PST Element	Score	Cumulative %
2.A-1	Supply Chain Partnering	40	13%
4.B-7	Link Mfging to Strategy	35	25%
1.C-4	LT reduction	25	33%
1.D-4	CAD & engineering	25	42%
2.B-3	JIT Inventory Control	20	48%
3.C-3	Cellular manufacturing	20	55%
3.E-4	Boundary Management	20	62%
1.B-3	Process Mapping	15	67%
4.C-3	Customer surveys	15	72%
4.E-4	Culture change	15	77%
4.B-1	Lean production	10	80%
4.B-4	Time based management	10	83%
2.C-2	Maintaining stock levels	10	87%
4.D-3	Technology Benchmarking	10	90%
1.A-4	QFD	5	92%
2.A-2	Customer Feedback	5	93%
1.B-6	Value Engineering	5	95%
4.C-2	Market research	5	97%
4.C-4	Bench. for customer Responsiveness	5	98%
4.C-5	BPR	5	100%
	Total	***300***	

Scoring by Root #3

RT-3 LT is not seen as a function of the waste in the process

Ref #	PST Element	Score	Cumulative %
4.B-4	Time based management	40	13%
4.B-1	Lean production	30	23%
1.C-4	LT reduction	30	33%
1.B-1	Reduced WIP	25	42%
1.B-2	JIT Production	25	50%
4.E-2	Empowerment	20	57%
4.E-4	Culture change	20	63%
3.A-1	Quality improvement teams	15	68%
1.B-3	Process Mapping	15	73%
3.C-3	Cellular manufacturing	15	78%
2.B-3	JIT Inventory Control	10	82%
1.C-5	Agile manufacturing	10	85%
1.A-3	TPM	5	87%
1.B-4	Design for Manufacturability	5	88%
1.B-6	Value Engineering	5	90%
2.B-4	Forecasting	5	92%
2.B-5	Logistics Management	5	93%
2.C-1	Predicting customer reauirements	5	95%
1.D-3	Automation	5	97%
1.D-4	CAD & engineering	5	98%
1.D-5	New Process Development	5	100%
	Total	300	

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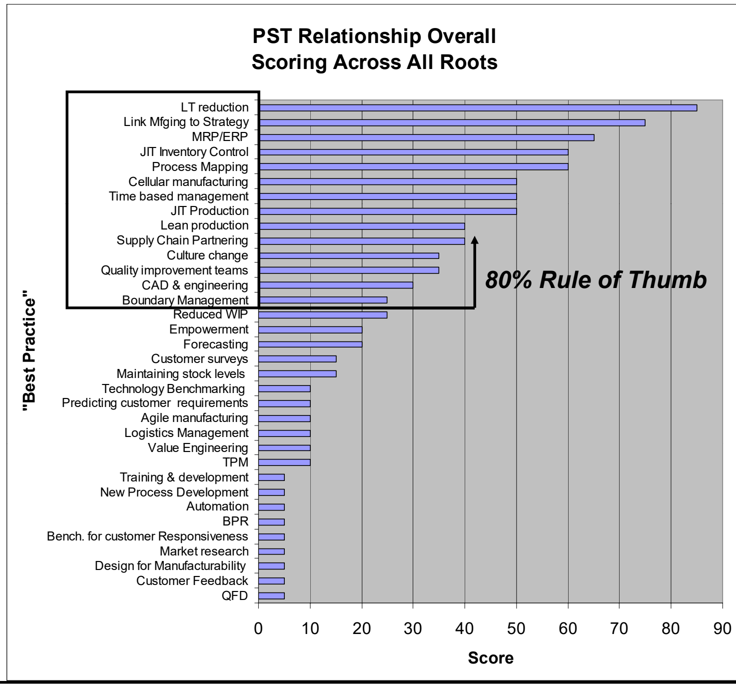
Case Study: Beta



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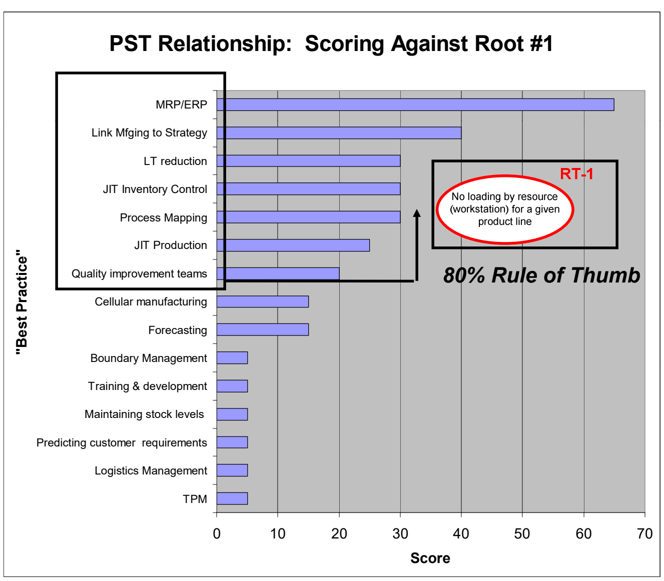
Case Study: Beta

Recommendation #1



Recommendation #1

Develop ability to compare requirements with the capacity of key workstations. This will enable the constraint to be identified and appropriate operational measures to be tracked. This should guide improvement actions for increasing system capacity.

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Linking PST Elements to Recommendation #1

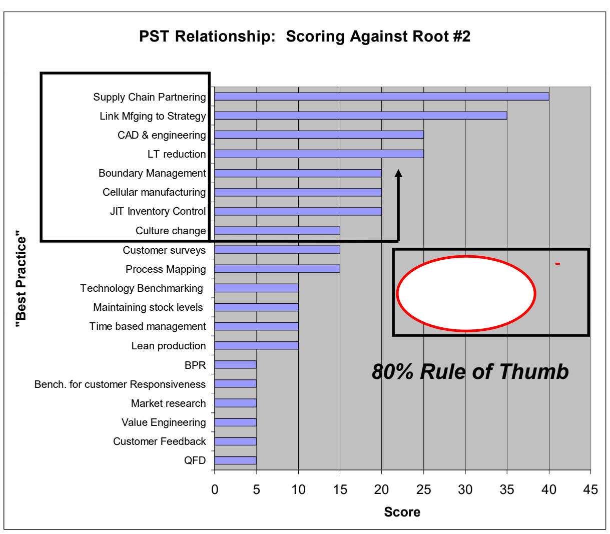
Recommendation #1

*Develop ability to compare requirements with the capacity of key workstations **(3.D-4)**. This will enable the constraint to be identified **(1.B-3)** and appropriate operational measures to be tracked **(1.B-2)**. This should guide improvement actions **(3.A-1, 1.B-2)** for increasing system capacity **(4.B-7)**.*

Prioritized PST Elements for Root #1

Ref #	PST Element
3.D-4	MRP/ERP
4.B-7	Link Mfging to Strategy
1.B-3	Process Mapping
2.B-3	JIT Inventory Control
1.C-4	LT reduction
1.B-2	JIT Production
3.A-1	Quality improvement teams

Recommendation #2



Recommendation #2

Develop an overall business plan for establishing the value of rapid lead-time capability. This includes exploring partnerships with suppliers of key raw materials, reorganizing production operations to facilitate flow, finding ways of streamlining pre-production operations, and rationalizing appropriate capital investments. Of particular promise are ways to reduce design complexity (e.g., parametric CAD).

Case Study: Beta

Linking PST Elements to Recommendation #2

Recommendation #2

*Develop an overall business plan for establishing the value of rapid lead-time capability **(1.C-4, 4.C-3)**. This includes exploring partnerships with suppliers of key raw materials **(2.A-1)**, reorganizing production operations to facilitate flow **(3.C-3, 1.B-3, 2.B-3)**, finding ways of streamlining pre-production operations **(3.E-4)**, and rationalizing appropriate capital investments **(4.B-7)**. Of particular promise are ways to reduce design complexity - e.g., parametric CAD **(1.D-4)** .*

Prioritized PST Elements for Root #2

Ref #	PST Element
2.A-1	Supply Chain Partnering
4.B-7	Link Mfging to Strategy
1.C-4	LT reduction
1.D-4	CAD & engineering
2.B-3	JIT Inventory Control
3.C-3	Cellular manufacturing
3.E-4	Boundary Management
1.B-3	Process Mapping
4.C-3	Customer surveys
4.E-4	Culture change

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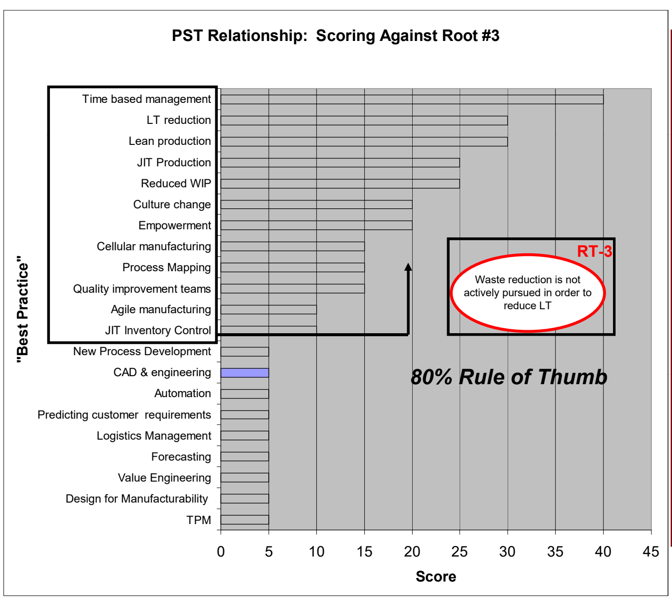
Recommendation #3



Recommendation #3

Develop a value stream map both "as is" and "to be" for lead-time sensitive products. The "as is" case illustrates the waste involved in the total process. This should include the key activities (i.e., receipt, design, purchase, and fabricate), and the calculation of percent "value add" time for comparison against world class performance. The "to be" case establishes the vision for substantial process improvement. The mapping and transition effort should include a broad cross section of team members.

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Case Study: Beta

Linking PST Elements to Recommendation #3

Recommendation #3

Develop a value stream map ***(1.B-3)*** *both "as is" and "to be" for lead-time sensitive products* ***(1.C-4).*** *The "as is" case illustrates the waste involved in the total process. This should include the key activities (i.e., receipt, design, purchase, and fabricate), and the calculation of percent "value add" time for comparison against world class performance* ***(4.B-4).*** *The "to be" case establishes the vision for substantial process improvement* ***(3.C-3, 4.E-4, 1.B-1, 4.B-1).*** *The mapping and transition effort should include a broad cross section of team members* ***(3.A-1).***

Prioritized PST Elements for Root #3

Ref #	PST Element
4.B-4	Time based management
4.B-1	Lean production
1.C-4	LT reduction
1.B-1	Reduced WIP
1.B-2	JIT Production
4.E-2	Empowerment
4.E-4	Culture change
3.A-1	Quality improvement teams
1.B-3	Process Mapping
3.C-3	Cellular manufacturing

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Case Study: Beta

Case Beta: Mapping of PST Elements to Recommendations

Ref #	PST Element	Total Score (overall)	Cumulative %	Rec_1	Rec_2	Rec_3
1.C-4	LT reduction	85	9%		X	X
4.B-7	Link Mfging to Strategy	75	18%	X	X	
3.D-4	MRP/ERP	65	25%	X	X	
1.B-3	Process Mapping	60	32%		X	X
2.B-3	JIT Inventory Control	60	38%		X	
1.B-2	JIT Production	50	44%	X		
4.B-4	Time based management	50	49%			X
3.C-3	Cellular manufacturing	50	55%		X	X
2.A-1	Supply Chain Partnering	40	59%		X	
4.B-1	Lean production	40	64%			X
3.A-1	Quality improvement teams	35	68%	X		X
4.E-4	Culture change	35	72%	X		X
1.D-4	CAD & engineering	30	75%		X	
1.B-1	Reduced WIP	25	78%			X
3.E-4	Boundary Management	25	81%		X	
2.B-4	Forecasting	20	83%			
4.E-2	Empowerment	20	85%			
2.C-2	Maintaining stock levels	15	87%			
4.C-3	Customer surveys	15	88%		X	
1.A-3	TPM	10	89%			
1.B-6	Value Engineering	10	91%			
2.B-5	Logistics Management	10	92%			
1.C-5	Agile manufacturing	10	93%			
2.C-1	Predicting customer requirements	10	94%			
4.D-3	Technology Benchmarking	10	95%			
1.A-4	QFD	5	96%			
2.A-2	Customer Feedback	5	96%			
1.B-4	Design for Manufacturability	5	97%			
4.C-2	Market research	5	97%			
4.C-4	Bench. for customer Responsiveness	5	98%			
4.C-5	BPR	5	98%			
1.D-3	Automation	5	99%			
1.D-5	New Process Development	5	99%			
1.E-5	Training & development	5	100%			
	Total	*900*				

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Case Study: Beta

Transformation of UDEs into Recommendations

Undesirable Effects

- **UDE-1:**. Structural steel delivery is often late.
- **UDE-2 :** Standard Lead-Time's are limiting higher margin volume
- **UDE-3:** Capacity is not managed as a performance measure

Root Causes

- **RT-1:** No loading by resource (i.e., workstation) for a given product line.
- **RT-2:** No market operations plan on business value of the development of a rapid lead-time capability.
- **RT-3:** Waste reduction is not actively pursued in order to reduce lead-time.

Selected PST Elements

3.E-2	Team based work
1.E-5	Training & development
4.E-4	Culture change
4.E-5	Learning climate
3.A-4	Quality training
4.D-5	Six Sigma
1.E-2	Multi-Skilling
4.E-1	HRM strategy
3.C-3	Cellular manufacturing
1.E-4	Appraisal
3.A-1	Quality improvement teams
3.A-2	Operator responsibility
3.A-3	Quality feedback to operators
4.B-1	Lean production
3.E-3	Job Enrichment

Recommendations

- **Rec_1:**. *Develop ability to compare requirements with the capacity of key workstations. This will enable the constraint to be identified and appropriate operational measures to be tracked. This should guide improvement actions for increasing system capacity.*
- **Rec_2:** *Develop an overall business plan for establishing the value of rapid lead-time capability. This includes exploring partnerships with suppliers of key raw materials, reorganizing production operations to facilitate flow, finding ways of streamlining pre-production operations, and rationalizing appropriate capital investments. Of particular promise are ways to reduce design complexity (e.g., parametric CAD).*
- **Rec_3:** *Develop a value stream map both "as is" and "to be"" for lead-time sensitive products. The "as is" case illustrates the waste involved in the total process. This should include the key activities (i.e., receipt, design, purchase, and fabricate), and the calculation of percent "value add" time for comparison against world class performance. The "to be" case establishes the vision for substantial process improvement. The mapping and transition effort should include a broad cross section of team members.*

Case Study: Beta

Client Feedback

Recommendation	Effectiveness *"The recommendation, if implemented, would have a substantially positive impact on the manufacturing enterprise."* *Please rate each recommendation on a score of 1-5* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	Implementability *"The recommendation is practical and implementable without spending excessive time and resources."* *Please rate each recommendation on a score of 1-5* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	Overall Score
Rec_1:	4	3	7
	Important, if not critical, to develop the ability to compare demand verses capacity both for tracking improvement and targeting areas for improvement.	*Challenging to implement due to job shop type environment*	
Rec_2:	4	4	8
	Essential to take advantage of perceived market opportunities for increased profitability.	*Lots of potential - particularly in the design side. The material and purchasing side may not be realized quite as easily.*	
Rec_3:	4	4	9
	Critical to support the lead time business segment and successful improvements will also reduce overall wastes - thus increasing overall efficiencies.	*The recommendation is entirely feasible and practical. It is the only way really to attack the problem.*	

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Client Feedback

General Comments
Main benefit was the clarification of thoughts. It helped to tie known issues and improvement processes together in order to drive focus on the key elements. The assessment methodology did not reveal anything totally new, really helped to organize thoughts and plans.
Particularly helpful was the current reality tree through the cause and effect analysis. Drilling down into a set of root causes was very insightful and helped to clarify interactions not previously known.

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Feedback after Evaluation

Client Feedback at the Evaluation Stage: (SMR - Plant Manager)
The biggest UDE was not previously on the radar screen… but after going through this stage it became apparent that the steel delivery is the number one issue. The lack of key measurables became much more apparent. A couple of key measures are either missing or not actively managed. The LT issue was confirmed as an opportunity.
Concern about the plant manager being present for all the meetings. The concern was that this would inhibit the group's openness. However, it did not appear as if my presence impacted the discussions. There was much value in sitting through and listening to the discussions as opposed to reading it after the fact in a report.

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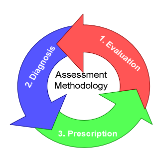
Feedback after Diagnosis

Agree with all three of the root causes.

The logic of tying together the cause and effect linkages helps to clarify the issues.



Case Study - Gamma:

Pilot of Taxonomy Based Assessment Methodology (TBAM)

Assessment Team:
Clay Walden, Steve Puryear,
August 16-17, 2007

Case Study: Gamma

August 16-17, 2007

Assessors: Clay Walden, Steve Puryear (Mississippi State University, CAVS Extension)

Scope: Focus on the on-site assessment of core functions which support the product manufacturing. On site functions include Human Resources, Accounting, Quality, Service, Manufacturing, Purchasing, and Planning.

Client Participants

Plant Manager
HR Manager
Engineering Manager
Quality and Service Manager
Planner
Purchaser
Controller

Products: Precision optical components
Prisms
Lenses

Markets
Defense
Commercial

Employees
80 employees
40 Hourly
40 Office

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Overview:

Low volume, high mix jobs

Specialize in very difficult to manufacture products that require extremely tight tolerances.

Overall in a growing market and they can sell their capacity.

Very sensitive processes - 30 to 40 variables may effect the quality of each major process.

Development of shop floor employees to achieve a basic level of performance is often greater than one year.

Generally in a growth market with a product that is used in a wide variety of applications which has enabled steady business volume over many years.

Family owned and run business.

Particularly known in their markets has providing an exceptionally high level of product quality as evidenced by a 1% field return which is exceptional in their industry.

On Time delivery is not satisfactory and is running at approximately 60%.

Internal scrap rate is very high which has historically been approximately 40%.

Stable financial performance where cashflow is not a problem and access to capital is not a problem.

Each piece is 100% inspected after each major step in the process. Inspection is carried out by both operators and inspectors.

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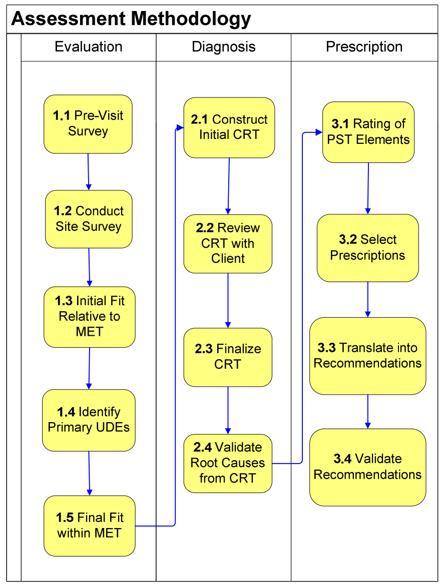
Detailed Methodology



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Evaluation Stage

Objective: Identify the client's fit within the Manufacturing Enterprise Taxonomy (MET) and identify Undesirable Effects (UDEs) using the MET based survey instrument.

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Case Study: Gamma

1.0 Business Environment

1.0 Business Environment *"descriptive"*		Level 1	Score →	Level 5	***Evidences***
1.1 Competitive Environment	***1.1.1 Intensity of Competition***	Numerous Competitors	3	Few Competitors	*Long standing relationships between three to four major competitors. Each competitor has its niche. Gamma has their strength in difficult to manufacture prisms and lenses. Product has broad application in a variety of diverse products (night vision gogles, submarines, fire control systems, semi-conductor, ...). They face different competitors in different markets. Major customers (e.g., Northrop Grumman, Raytheon) are big defense contractors, which comprise 80% of their volume. About 20% of their business is commericial (e.g., semiconductors). About 80% of their volume is classified as "tight" tolerance parts and 20% of their volume have more "open" tolerances - more competitors for these products.*
3.50	***1.1.2 Stability/Emerging Threats***	Unpredictable Threats	4	Stable/ Few Threats	*Due mostly to heavy defense work off shore sourcing has not been a problem. However, Chinese product has gotten much better and it is much cheaper (much less than half the price). Off shore competition has impacted the commercial businesses more (e.g., binocular, rifle scopes, medical applications). However, several years ago commercial made up a much larger proportion of their sales volume. An additional concern is that almost all of their core raw material originates overseas in Malaysia and Japan. Another business threat is the availability of skilled labor at affordable wages. Their workforce was recently greatly impacted by recent hurricane and following scarcity of labor at reasonable costs. Due to specialty nature of their manufacturing processes and product expertise major customers deciding to in-source does not appear likely. Since they have been in business ~40 years, Gamma has not experienced any radical changes in their business volume. So while they are not without some level of threats, in general they appear to operate within relatively stable conditions.*
1.2 Regulatory Environment	***1.2.1 Product Regulations***	Many Regulations	4	Few Regulations	*Very little product related regulations other than the "lead free" requirements from the DOD.*
4.00	***1.2.2 Process Regulations***	Many Regulations	4	Few Regulations	*Very little beyond the typical OSHA and EPA requirements (handling and disposal of hazardous chemicals acetone, polishing chemicals, ...).*
1.3 Market Conditions	***1.3.1 Seasonality Effect***	Heavy Seasonality	4	No Seasonality	*Not much seasonality but orders due pick up at the first of the year, down somewhat in the summer, and pick up again in the fall.*
4.00	***1.3.2 Level of Growth***	No Growth/Shrinking	4	High Growth	*Overall they are in a growing market in terms of both commercial and defense applications. This stems from the fact that numerous applications have been found and are continuing to be found for highly precise optical systems in which their product is a key component.*
Business Environment		***Average Score***	**3.83**		

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Case Study: Gamma

2.0 Leadership

2.0 Leadership *"prescriptive"*		Level 1	Score →	Level 5	***Evidence***
2.1 Strategic Planning & Deployment	***2.1.1 Formal Strategy***	"All things to all"	5	Clear: Porter's Generic Strategy	*In terms of Porter's generic strategies - they clearly fit in the differentiated product with narrow market scope. They clearly want to grow the business but they do not want to get into the higher volume, more commodity type of work. Their strategy is to stay with the more dificult customer manufacturing type of work which they feel is their strength. Strategically they want to move into becoming more of a sub-assembly provider rather than just the pure optical piece. This would enable them to get higher margins. However, it means they need to develop higher level engineering skills in order to support the sub-assembly design. Senior mangement realizes this is a long term goal and one that is not easily obtained. Business is family owned with three brothers managing critical aspects of the business.*
3.5	***2.1.2 Deployment***	few know / little involvement	2	widely understood & clear link to actions	*They have recently focused on improving the level of communication to the floor and other employees.*
2.2 Culture of Empowerment	***2.2.1 Level of Participation***	Restricted Involvement	1.5	High level of Involvement	*The level of participation in the language of the senior manager is minimal. Their seems to be some reluctance for some of their key employees to really step up. Routinely problems are discussed but effective follow up is not strong. However recent rounds of two kaizen events conducted last year has helped, but clearly Gamma does not exhibit a high level of involvement of employees to improve daily operations. This is a source of frustration to senior leadership.*
1.5	***2.2.2 Effectiveness of Participation***	Little evidence of impact	1.5	Evidence of substantial Impact	*There has not been a strong track record from the perspective of senior management of a broad cross section of employees identifying root causes of problems and developing quick and effective counter measures. Their appears to be some reluctance between employees from different functions working as a team. Employees tend to view their roles along strictly functional lines. Another area of opportunity is for some of their more experienced and highly skilled employees to become more actively involved in developing proficiencies in others. Senior management thinks that they need more of their key employees to take more initiative, work better cross functionally, and be willing to take more risks. Unless this happens, according to senior management, the company cannot grow.*
Leadership		***Average Score***	**2.50**		

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Case Study: Gamma

3.0 Customer / Market Focus

3.0 Customer / Market Focus "prescriptive"		***Level 1***	***Score***	***Level 5***	***Evidence***
3.1 Translation of Requirements	***3.1.1 Design/Order***	Informal / Unstructured	4	intentional and formal	*Customers provide the detail specification for the order via prints. There is no problems with interpreting design intent. Requirements include both dimensional, cosmetic, and performance requirements. Occasionally (less than 5% of the time) customers will need help in specifying exactly what they need. In those cases an optical designer will be used. The RFP is reviewed and Gamma makes the decision whether or not they have the required manufacturing capabilities to produce the order within the delivery requirements. Due to wide variety of end item products, the requirements for each order are noted in a job packet that travels with the order through the shop.*
3.25	***3.1.2 Feedback/Reaction***	few know / little involvement	2.5	widely understood & clear link to actions	*A feedback loop has been defined through the ISO 9000 requirements. Gamma has established a Customer Satisfaction Index that is based on the following criteria: returned materials, on-time delivery, service rating (based on phone calls logs). Biggest opportunity for improvement is on the measure of on-time delivery performance. Good measuremnt but lacking on strongly connecting it to drive improvements.*
3.2 Positioning / Value	***3.2.1 Customer Value***	No Clear way to identify (informal)	2.5	Clearly drives all actions (structured)	*Gamma essentially is selling the ability to perform contract manufacturing within a specialty niche optical component. They have established a long running reputation for exceptionally high quality products. They experience about a 1% return rate which is extremely good given the nature of their product. However at a high cost of internal failure rate (i.e., 30-40%) and less than desired on-time delivery performance (i.e., ~60%). Clearly the high emphasis on quality drives action, however they have yet to find a satisfactory strategy that maintains the high quality levels with satisfactory throughput. Their measure of CSI is running 60%-80%.*
3.50	***3.2.2 Dimensions of Performance***	No Sense of Relative Priorities	4.5	Clear Understanding	*Unless a minimum level of quality is provided then this is a disqualifier. Gamma is generally competitive on price but do not desire to be not the lowest. Improving on delivery performance is the biggest opportunity to make the most positive difference. They are successful in landing about 60% of the jobs they quote. Senior management views customer preferences as following: quality is first, delivery is second, and price is third.*

Customer/ Market Focus ***Average Score*** **3**

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Case Study: Gamma

4.0 Information & Knowledge Management

4.0 Information & Knowledge Management "descriptive"		***Level 1***	***Score***	***Level 5***	***Evidence***
4.1 Access to Information & Knowledge	***4.1.1 Availability of Data to Support Decision Making***	Difficult to obtain & interpret	4.5	Readily available & understood	*"Home grown" production management system has been developed using access. Data on past performance seems to be readily available. Access database developed for job tracking, reporting of yield and due date performance, and productivity by department and by employee. The job tracking is a report is produced showing the status of each job's pieces by process location. It also includes the due date and by knowledge of the job characteristics you can determine the status so that you can determine if there is a problem. Generally, a level of accessibility to performance measurement type of data.*
3.00	***4.1.2 Availability of Product/Process Knowledge***	Difficult to obtain & interpret	1.5	Readily available & understood	*Job specific information is contained in a job packet that travels with the order. This includes notes on the conditions under which the last time the job was run and a history of process changes implemented needed in order to run the part during the previous order. Job specific information requires a relatively high level of experience and skill to read and interpret. Thus the effectiveness of this information depends heavily on the person. Job packets are in place to record process settings used to produce order the last time (note could be 12-18 months ago). However, documentation is not always clear and requires a high degree of processes and product knowledge to properly interpret. Due to their large diversity in the number of jobs run and the past attention to detail - keeping current documentation on each job is both time consuming and difficult.*
4.2 Supportive of Improvement Efforts	***4.2.1 Operations Data/Information***	Difficult to obtain & interpret	4	Readily available & understood	*Almost any report involving production throughput, yield, and delivery can be produced very quickly. Biggest problem is that product can fail based on any number of attributes - checking is censored after the first failure is identified.*
3.50	***4.2.2 Financial Data/Information***	Difficult to obtain & interpret	3	Readily available & understood	*Capacity is loaded based on total business dollars associated with jobs. There is a goal established for each department and overall. Rough-cut measure of departmental capacity loading is business dollars loaded to total targeted dollars.*

Information & Knowledge Management ***Average Score*** **3.25**

100

Case Study: Gamma

5.0 Human Resources

5.0 Human Resources "prescriptive"		Level 1	Score	Level 5	Evidence
5.1 Maturity in Teaming	**5.1.1 Level of Team Success**	Limited / Informal	2	Frequent / Formal	*Some isolated evidence of success due to the work of teams operating in a structured manner. Last year two kaizen events were held by outside facilitators which were well received and some evidence of improvement. Clearly the level and effectiveness of team work has not reached senior management's expectations. Their plant environment is very amicable, but not very effective from a teaming perspective.*
1.75	**5.1.2 Qualities Considered in Hiring/Promotion**	Task Skills dominate	1.5	Balance Between Task & Teaming Skills	*The work of operators is very technical and to perform well requires a very analytical mind that can visualize the manufacturing processes in three dimensions the interaction of the tool and the work piece as well as taking measurement and making the right decision with respect to proper process adjustments (offsets, Lapp mixture, ...). Definitely task skills dominate. Gamma has questioned its employee development model from the standpoint of promoting effective operators into supervisory positions. It takes them out of the job that they do best and sometimes they are not very effective as a supervisor. They have stsarted to bring in people from the outside in order to promote a more open perspective. Employee turnover in certain jobs has been very high. For example, in the inspection area they have hired 4 new inspectors since Christmas.*
5.2 Employee Skill Level	**5.2.1 Level of Cross Functional Mastery**	Primarily within function	2	Mastery of a variety of skills is widely deployed	*This is an area they have currently been working hard in to expose people to other functions. Much more encouragement now for people to share their process knowledge to the more junior employees. For whatever reason in the past this was not promoted. This developed into a culture that did not share information. Also ISO 9000 was a good step toward beginning to force documentation of key process control conditions. Also they have started to encourage a real mentoring to occur between senior operators and those who are less experienced - but have a long way to go to institutionalize this. Typically people on the floor stay focused on their own functions (e.g., milling, polishing, ...).*
2.25	**5.2.2 Mastery of Key Skills**	Not identified and/or inexperience	2.5	Identified & clear strengths exist	*A great disparity exists between those operators that have developed a high skill level and those who are just beginning. It takes a relatively long time to develop people to perform at an acceptable level of performance. Some do not ever achieve it. In the milling process it takes a person about 6 months and about 1 year in the polishing operation. A training program and manual exists but needs to re-energized. Also they have dealt with a heavy turnover in very experienced workers related to the Hurricane. Some have moved away and others have moved to higher paying far less technical jobs at the newly re-opened Casino's. Gamma has identified the training issue has a clear need (4) but currently operate with a much lower experience and expertise level among operators than desired (2). Some of their people will not ask for help and keep working on jobs making changes to see if they can get the job to run. Recently they had a case where one operator took 4 weeks to get 75 pieces produced. Their culture is more to work in isolation and not to ask for help.*
Human Resources		**Average Score**	**2**		

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Case Study: Gamma

6.0 Development of Products and Processes

6.0 Development of Products & Processes "prescriptive"		Level 1	Score	Level 5	Evidence
6.1 Product Development	**6.1.1 New Product Development Lead-Time**	Inferior to Competition	3	Superior to Competition	*Since they really do not develop new products - they are a "niche player - contract manufacturer." This element did not directly apply. However, they do take on completely new jobs and they must develop the processes for producing these jobs. They do believe they have an advantage over the competition in terms of their ability to produce new and different products that are difficult to manufacture. Hitting quoted lead-times is a challenge.*
3.50	**6.1.2 Effectiveness of Product Development**	Inferior to Competition	4	Superior to Competition	*In terms of effectiveness they do believe they have an advantage over the competition in terms of their ability to produce new and different products that are difficult to manufacture.*
6.2 Process Development	**6.2.1 New Process Development Lead-Time**	Inferior to Competition	3.5	Superior to Competition	*They were the first to bring in CNC technology both in terms of milling and polishing within the last few years. Now their competition has caught up on that. Gamma is looking for the next thing to stay ahead of the competition. The next biggest opportunity appears to be in how they flow product, reducing internal defects, and improved ability to hit delivery dates.*
3.75	**6.2.2 Effectiveness of New Process Development**	Inferior to Competition	4	Superior to Competition	*They were the first to bring in CNC technology both in terms of milling and polishing within the last few years. Now their competition has caught up on that. Gamma is looking for the next thing to stay ahead of the competition. The next biggest opportunity appears to be in how they flow product, reducing internal defects, and improved ability to hit delivery dates.*
Development of Products & Processes		**Average Score**	**3.63**		

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Case Study: Gamma

7.0 Product and Process Characterization

7.0 Product & Process Characterization "descriptive"		Level 1	Score	Level 5	Evidence
7.1 Product Characterization	7.1.1 Product Lifetime	Short	4	Long	Service life of products is quite long greater than 20 years is not uncommon.
	7.1.2 Product Volume	Low	1.5	High	Low volume runs 50-100 pieces is not atypical. Common timeframes between repeat orders is 6 to 18 months. Prisms tend to have higher volume than spherical (i.e., lenses) products.
3.38	7.1.3 Product Complexity	Low	4	High	Simply geometry - but product requirements are not easy to achieve (e.g., flatness tolerances measured in fringes). highly precise products with high flatness and radius tolerances as well as exceptional light diffraction properties (measured in fringes). Relatively simple geometry. High level of variety in terms of large number of combinations relative to types of raw material, dimensional differences, and performance attributes.
	7.1.4 Product Variety	Low	4	High	About 70% of their jobs are jobs that they have done before - approximately 30% of their jobs are totally new. However, only about 30% of their jobs are repeated often enough so that using current approaches they are able to develop some level of proficiency.
7.2 Process Characterization	7.2.1 Process Capacity	Excess	3	Minimal	Currently near maximum for staffing levels (day shift is full and selected machines are run on second sift). Constraint is in the plant - market can take everything that they can produce. Significant "latent" capacity is being lost in terms of high rate of internal scrap (e.g., 40% scrap)
3.00	7.2.2 Layout of Processes	Functional	2	Cellular	Plant is laid out in a highly functional manner - dedicated milling area, polishing area, edging area, and coating area. One exception is an experimental CNC cell - CNC milling and CNC polishing manned by one operator for the spherical lenses products. Success of this pilot cell has been somewhat limited due to problems with the CNC polishing machines. Process results in terms of product quality are very much set-up dominate. No physical requirements for separation other than possibly coating.
	7.2.3 Process Integration	Low	4	High	Relatively high - can purchase stock in raw form or rough milled. Based upon pricing and load within rough milling. Mostly the raw glass comes in in discrete pieces that are machines.
7.3 Product-Process Characterization	7.3.1 Goldratt's VAT	Unclear Fit	3	Clear Fit	Mostly a "V" plant if problems occur the individual glass pieces can be cut down to something smaller. Little joining and assembly operations (some exceptions).
3.50	7.3.2 Hayes-Wheelwright Matrix	Unclear Fit	4	Clear Fit	Disconnected line - batch

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Product & Process Characterization — **Average Score** 3.28

Case Study: Gamma

8.0 Management of Extended Enterprise

8.0 Management of Extended Enterprise "prescriptive"		Level 1	Score	Level 5	Evidence
8.1 Supply Chain Management	8.1.1 Product Requirements	Unclear	4	Clear	Almost all raw materials purchases (80%) are driven by a job. The 20% of their raw materials are common across a variety of jobs and are ordered based upon a rough forecast. Customer prints are very clear in terms of the raw material specification.
3.00	8.1.2 Ordering & Inventory Requirements	Unclear	2	Clear	Suppliers percentage on-time to Gamma is between 60% and 70%, which is not very high. However, most of Gamma's delivery issues in the opinion of the key staff lies with the unpredictability of their own internal processes. "Gut feel" is about 2/3 of their delivery problems are due to lack of internal control of their processes and about 1/3 due to late delivery of suppliers. Rush orders make it difficult for the suppliers to respond.
8.2 Distribution Chain Management	8.2.1 Finished Goods Management	Unclear	3	Clear	Typical order LT is 8-10 weeks. Finished goods are kept for common runners. Frequently, they will set up and run more than is needed in order to ensure that after production has completed they will have enough to fill the order. Their yields are not predictable and sometimes they will end up with more than was ordered. Those items are stored in finished goods. The process is very set-up intensive and once a "good" set up occurs they will try to run as many as they can.
2.25	8.2.2 Order Fulfillment Management	Not meeting Customer Desires	1.5	Regularly Meeting Customer Desires	On-time delivery is running at around 60% - Against a relatively long standard lead-time of 8 weeks - which is not an acceptable level of performance from the perspective of senior management.

Management of Extended Enterprise — **Average Score** 2.63

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9.0 Approach to Continuous Improvement

9.0 Approach to Continuous Improvement "Prescriptive"		Score: Level 1 →		Level 5	Evidence
9.1 Performance Measures	9.1.1 Strategic Alignment of Operational Measures	fuzzy connection	4	clearly articulated	Overall they have a very straightforward set of measures: percentage good, % bad by reason code, throughout, customer satisfaction index (returns, complaints, on-time delivery). In terms of emphasis departmental measures dominate - scrap rate, productivity by area, by workstation, by person.
4.25	9.1.2 Balanced & Multi-dimensional	single dimension (e.g., cost)	4.5	multi-dimensional & balanced	Previous experience with emphasizing the fundamental need to improve internal quality through an internal competition between departments resulted in a drop in throughput. Gamma has now changed its incentives to include both quality and throughput aspects of performance. Within Gamma's environment it is very easy to look for trade-offs between quality and throughput.
9.2 Process Focus	9.2.1 Identification of Key Processes	unsupported	2	documented & communicated	Generally these processes are managed in an independent manner - clear evidence that milling quality impacts polishing time.
	9.2.2 Constraints	unknown	2	known & managed	Generally there is sufficient machine capacity. The constraint in the overall opinion of key managers and engineers appears to be the capability of individual employees. This contributes greatly to the lack of being able to establish internal process control conditions. Level of interrelationships between process steps is not clearly known. It is unclear where the bottleneck is … may change based upon the job.
2.00	9.2.3 Emphasis on Variability & CT Reduction	none	2	drives action	The connection is understood but is not totally driving improvement actions. Customer lead-time has remained unchanged over several years.
9.3 Use of World Class Practices	9.3.1 Continuous Improvement Approach	informal	2	formal & intentional	Highly informal and infrequent use of recognized tools and world class practices. However, within the last few years have achieved ISO 9000 registration which had a generally positive impact. Last year two kaizen events were executed and participants were exposed to 5S, DMAIC, SPC, and DOE - overall efforts showed some positive impact.
2	9.3.2 Effectiveness	unclear	2	clear & documented	Beginning to see some improvement in quality (~10% improvement according to two of the senior managers). Initially they reduced throughput but have now recovered. Improvements has been slower to materialize than management would like.
9.4 Quality System	9.4.1 Formal System	Informal & unstructured	4.5	formal & registered	ISO 9001 registration
3.5	9.4.2 Effectiveness	conformance driven	2.5	performance driven	ISO 9000 has really helped them start to focus on improving their level of documentation. No indication of improving on-going effectiveness. Registration appears to be primarily customer driven though recognize importance of standardizing operations enabled via ISO 9001. Manufactruing process is characterized by 100% inpection after each step. Concern is that tolerances are so tight and measurement method is dependent on method that gage

Approach to Continuous Improvement | Average Score | 2.83

10.0 Enterprise Financial Health

10.0 Enterprise Financial Health "Descriptive"		Score: Level 1 →		Level 5	Evidence
10.1 Ability to Invest in Assets	10.1.1 Capital Availability	not possible / severely restricted	5	Adequate	Capital is generally available without borrowing. Capital expenditure are between $500K and $1M.
10.2 Liquidity	10.2.1 Cash Flow	severely restricted	5	sufficient	Cash flow is strong. Mostly dealing with large customers who do not have trouble paying. Cashflow seems to be strong and no evidence that any restrictions impact dialy operation.

Enterprise Financial Health | Average Score | 5.00

Case Study: Gamma

Summary of MET Survey Scoring

Category	Sub-category	Item	Score	Average for Category	Average for Taxon
1.0 Business Environment					
	1.1 Competitive Environment	1.1.1 Intensity of Competition	*3*	3.50	3.83
		1.2.1 Stability/Emerging Threats	*4*		
	1.2 Regulatory Environment	1.2.1 Product Regulations:	*4*	4.00	
		1.2.2 Process Regulations:	*4*		
	1.3 Market Conditions	1.3.1 Seasonality Effect	*4*	4.00	
		1.3.2 Level of Growth	*4*		
2.0 Leadership					
	2.1 Strategic Planning & Deployment	2.1.1 Formal Strategy	*5*	3.50	2.50
		2.1.2 Strategy Deployment	*2*		
	2.2 Culture of Empowerment	2.2.1 Level of Participation	*1.5*	1.50	
		2.2.2 Effectiveness of Participation	*1.5*		
3.0 Customer / Market Focus					
	3.1 Translation of Requirements	3.1.1 Design/Order	*4*	3.25	3.38
		3.1.2 Feedback/Reaction	*2.5*		
	3.2 Positioning / Value	3.2.1 Customer Value	*2.5*	3.50	
		3.2.2 Dimensions of Performance	*4.5*		
4.0 Information System & Knowledge Management					
	4.1 Access to Information & Knowledge	4.1.1 Availability to Data/Information to Support Decision Making	*4.5*	3.00	3.25
		4.1.2 Availability of Product/Process Knowledge	*1.5*		
	4.2 Supportive of Improvement Efforts	4.2.1 Operations Data/Information	*4*	3.50	
		4.2.2 Financial Data/Information	*3*		
5.0 Human Resources					
	5.1 Maturity in Teaming	5.1.1 Level of Team Successes	*2*	1.75	2.00
		5.1.2 Team Qualities Considered Strongly in Hiring/Promotion	*1.5*		
	5.2 Employee Skill Level	5.2.1 Cross Functional Encourgement	*2*	2.25	
		5.2.2 Opportunties for Developing Additional Skills	*2.5*		
6.0 Development of Products & Processes					
	6.1 Product Development	6.1.1 New Product Development Time	*3*	3.50	3.63
		6.1.2 Effectiveness of New Products Relative to Opportunity	*4*		
	6.2 Process Development	6.2.1 New Process Development Time	*3.5*	3.75	
		6.2.2 Effectiveness of New Processes Relative to Opportunity	*4*		
7.0 Product & Process Characterization					
	7.1 Product Characterization	7.1.1 Product Lifetime	*4*	3.38	3.28
		7.1.2 Product Volume	*1.5*		
		7.1.3 Product Complexity	*4*		
		7.1.4 Product Variety	*4*		
	7.2 Process Characterization	7.2.1 Process Capacity	*3*	3.00	
		7.2.2 Layout of Processes	*2*		
		7.2.3 Process Integration	*4*		
	7.3 Product-Process Characterization	7.3.1 Goldratt's VAT Logical Product-Process	*3*	3.50	
		7.3.2 Hayes-Wheelwright Matrix	*4*		
8.0 Management of Extended Enterprise					
	8.1 Supply Chain Management	8.1.1 Management of Requirements (Product & Ordering)	*4*	3.00	2.63
		8.1.2 Management of Incoming Inventory	*2*		
	8.2 Distribution Chain Management	8.2.1 Management of Finished Goods Inventory	*3*	2.25	
		8.2.2 Management of Order Fullfillment	*1.5*		
9.0 Approach to Continuous Improvement					
	9.1 Performance Measures	9.1.1 Strategic Alignment of Operational Measures	*4*	4.25	2.83
		9.1.2 Balanced & Multi-dimensional	*4.5*		
	9.2 Process Focus	9.2.1 Key Process Identification	*2*	2.00	
		9.2.2 Constraints	*2*		
		9.2.3 Emphasis on Variability & CT Reduction	*2*		
	9.3 Use of Specific World Class Practices	9.3.1 Formal Adoption of a CI Approach	*2*	2.00	
		9.3.2 Demonstration of Effectiveness	*2*		
	9.4 Quality System	9.4.1 Formal System	*4.5*	3.50	
		9.4.2 Demonstration of Effectiveness	*2.5*		
10.0 Enterprise Financial Health					
	10.1 Capital Availability	10.1.1 Capital Availability	*5*	5.00	5.00
	10.2 Liquidity	10.2.1 Cash Flow	*5*	5.00	

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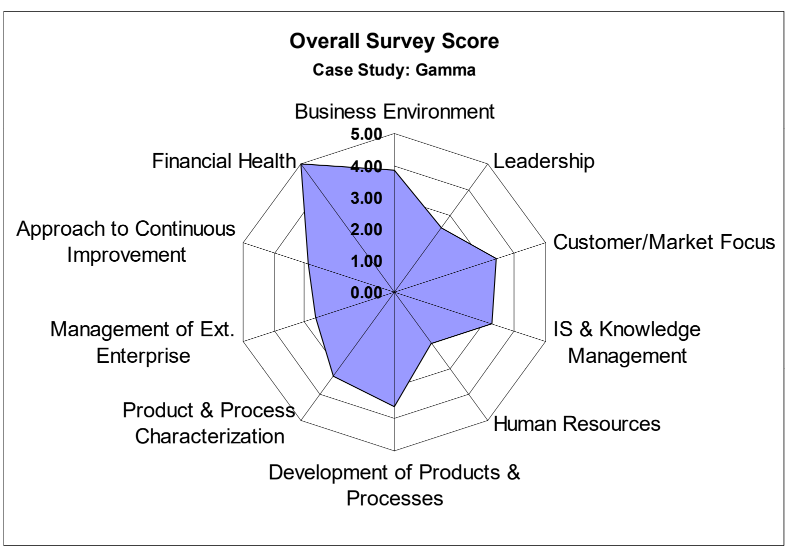
Case Study: Gamma

MET Scoring Across Major Attributes



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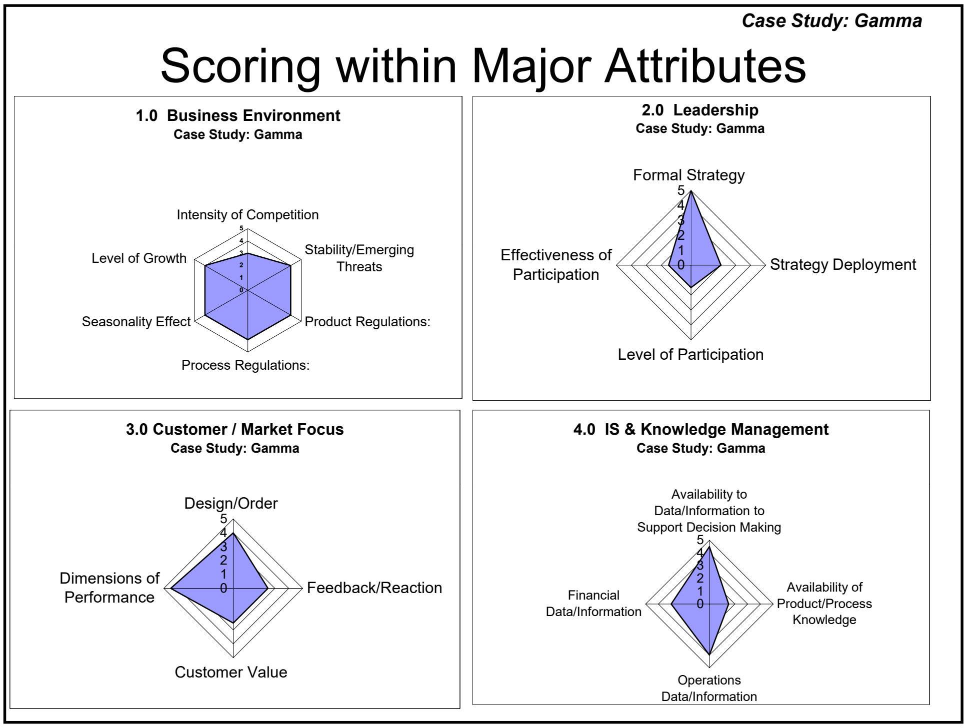
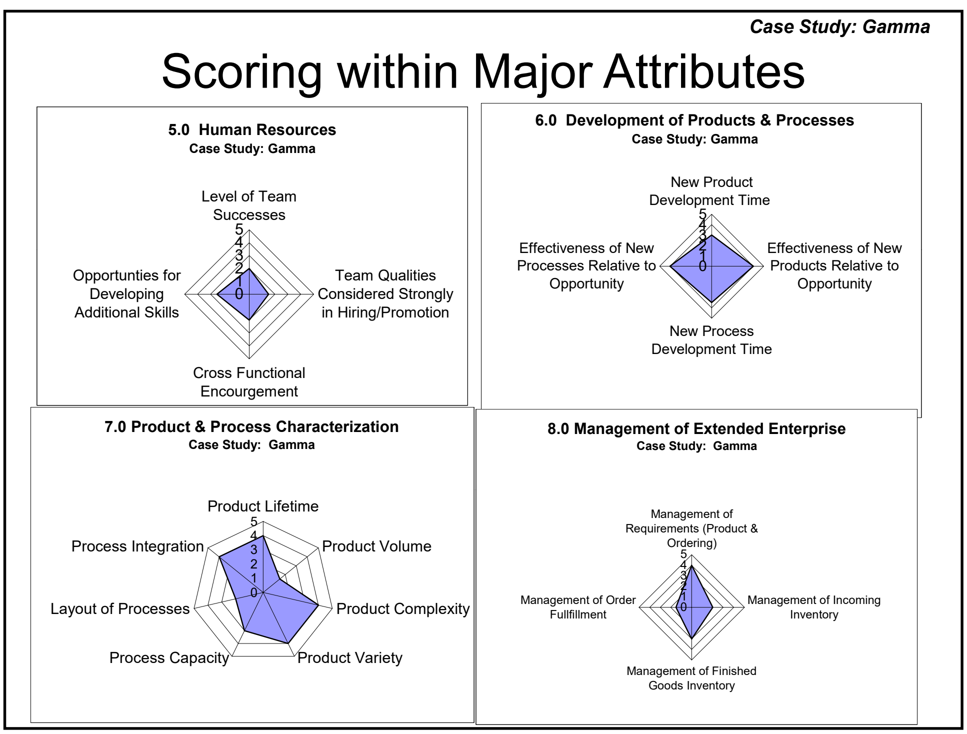
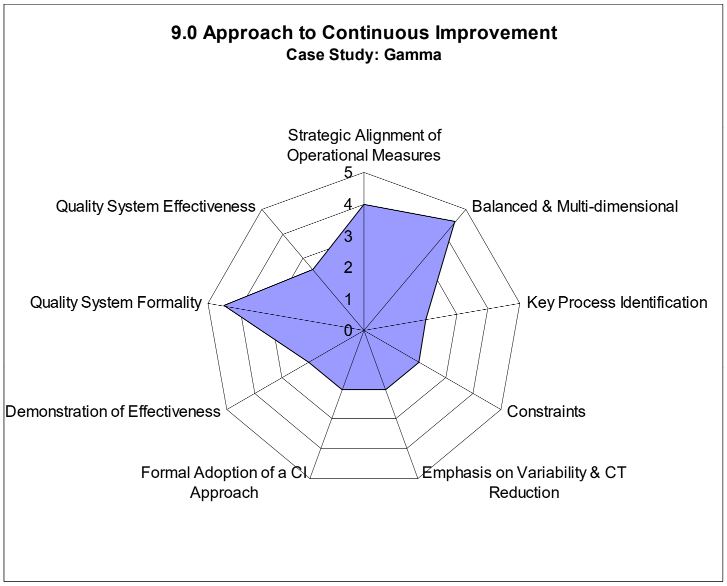

Case Study: Gamma
Scoring within Major Attributes
1.0 Business Environment
Case Study: Gamma
Intensity of Competition
Stability/Emerging Threats
Product Regulations:
Process Regulations:
Seasonality Effect
Level of Growth
2.0 Leadership
Case Study: Gamma
Formal Strategy
Strategy Deployment
Level of Participation
Effectiveness of Participation
3.0 Customer / Market Focus
Case Study: Gamma
Design/Order
Feedback/Reaction
Customer Value
Dimensions of Performance
4.0 IS & Knowledge Management
Case Study: Gamma
Availability to Data/Information to Support Decision Making
Availability of Product/Process Knowledge
Operations Data/Information
Financial Data/Information


Case Study: Gamma
Scoring within Major Attributes
5.0 Human Resources
Case Study: Gamma
Level of Team Successes
Team Qualities Considered Strongly in Hiring/Promotion
Cross Functional Encourgement
Opportunities for Developing Additional Skills
6.0 Development of Products & Processes
Case Study: Gamma
New Product Development Time
Effectiveness of New Products Relative to Opportunity
New Process Development Time
Effectiveness of New Processes Relative to Opportunity
7.0 Product & Process Characterization
Case Study: Gamma
Product Lifetime
Product Volume
Product Complexity
Product Variety
Process Capacity
Layout of Processes
Process Integration
8.0 Management of Extended Enterprise
Case Study: Gamma
Management of Requirements (Product & Ordering)
Management of Incoming Inventory
Management of Finished Goods Inventory
Management of Order Fullfillment

Case Study: Gamma

Scoring within Major Attributes



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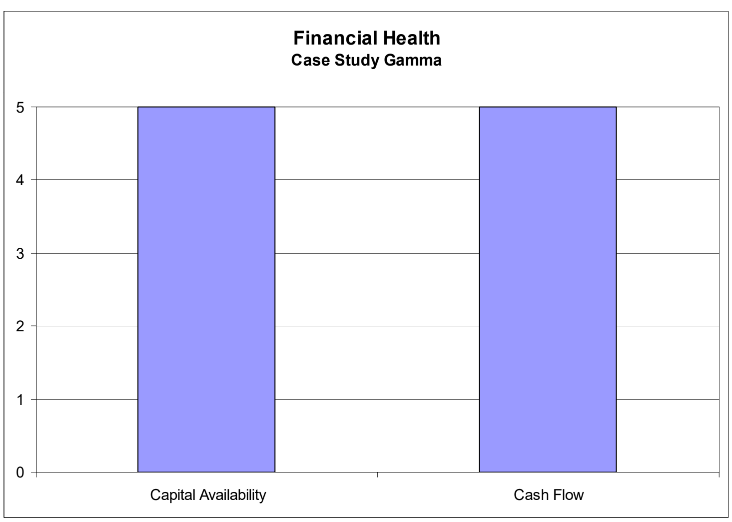
Case Study: Gamma

Scoring within Major Attributes



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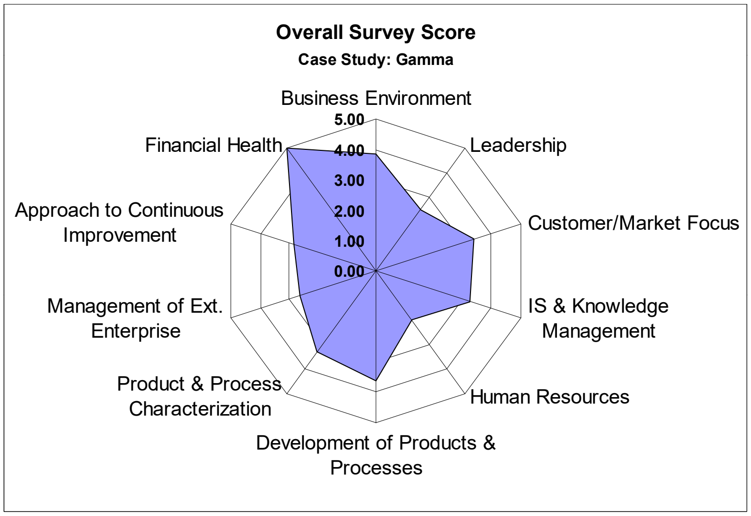
Scoring Across Major Attributes



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Case Study: Gamma

Prioritization of UDEs

Prioritization of UDEs Identified During the MET Survey		Case: Gamma	
	UDE	Overall	Cumulative Percentage
1	Process Control is difficult to maintain	30	30%
2	Middle management supervisory skills underdeveloped	20	50%
3	Takes too long to develop effective shop floor employees	15	65%
4	Internal failure rate is too high (i.e., scrap and re-work)	15	*80%*
5	Frequently customer due dates are missed	10	*90%*
6	Employee turnover is too high	10	*100%*
7		0	*100%*
8		0	*100%*
9		0	*100%*
	Total	100	

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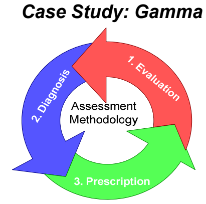
UDEs Selected for Probing During Diagnosis Phase

Highest Priority UDEs for Use in CRT Construction	
UDE-1	***Process Control is difficult to maintain***
UDE-2	***Middle management supervisory skills underdeveloped***
UDE-3	***Takes too long to develop effective shop floor employees***



Diagnosis Stage

Objective: Translate Undesirable Effects (UDEs) into Root Cause(s) through the use of Current Reality Tree.

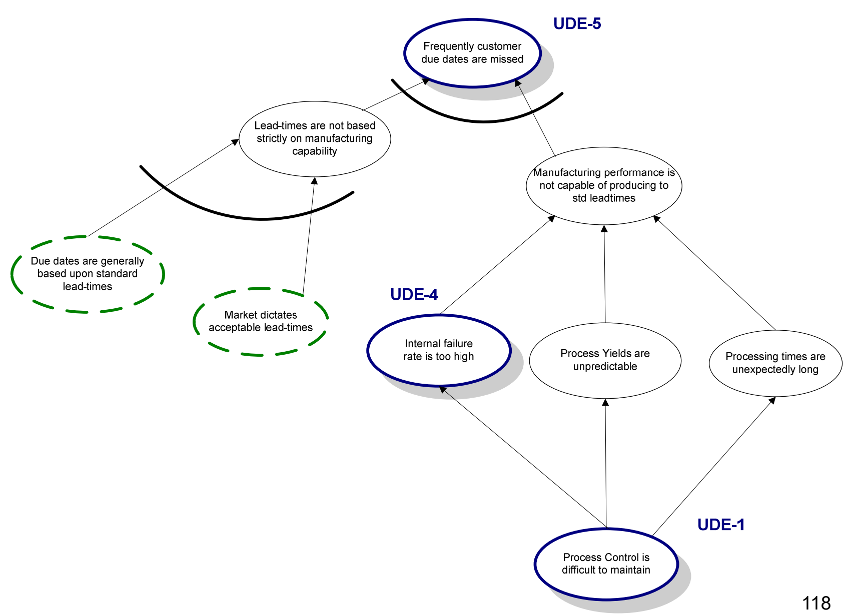
Current Reality Tree: Legend

UDE-2

Cause and Effect Linkage

Case Study Gamma

Page 1



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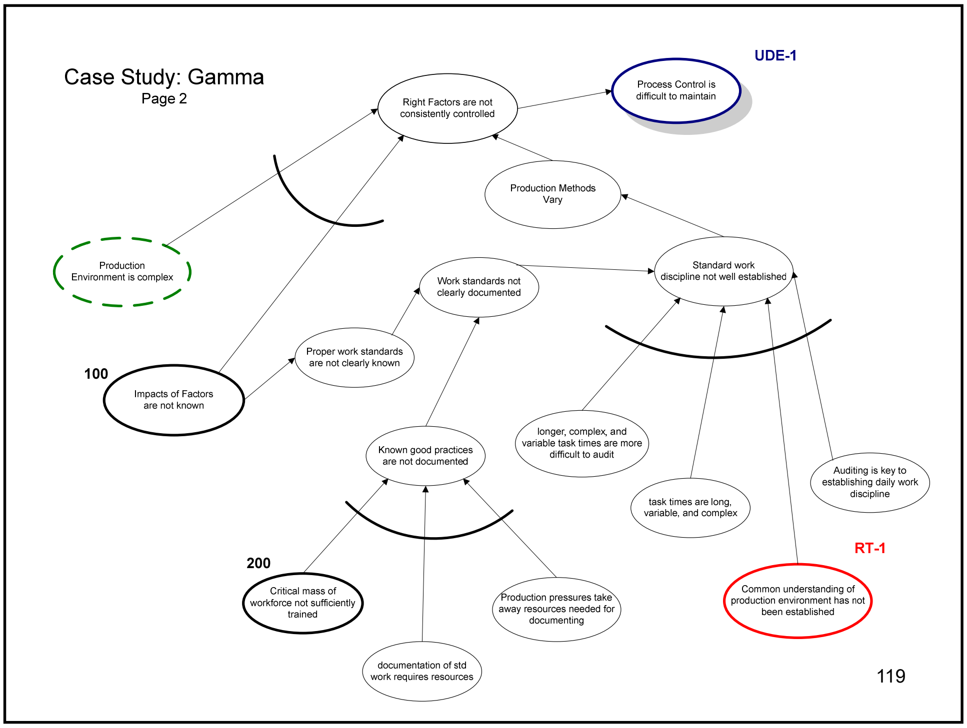
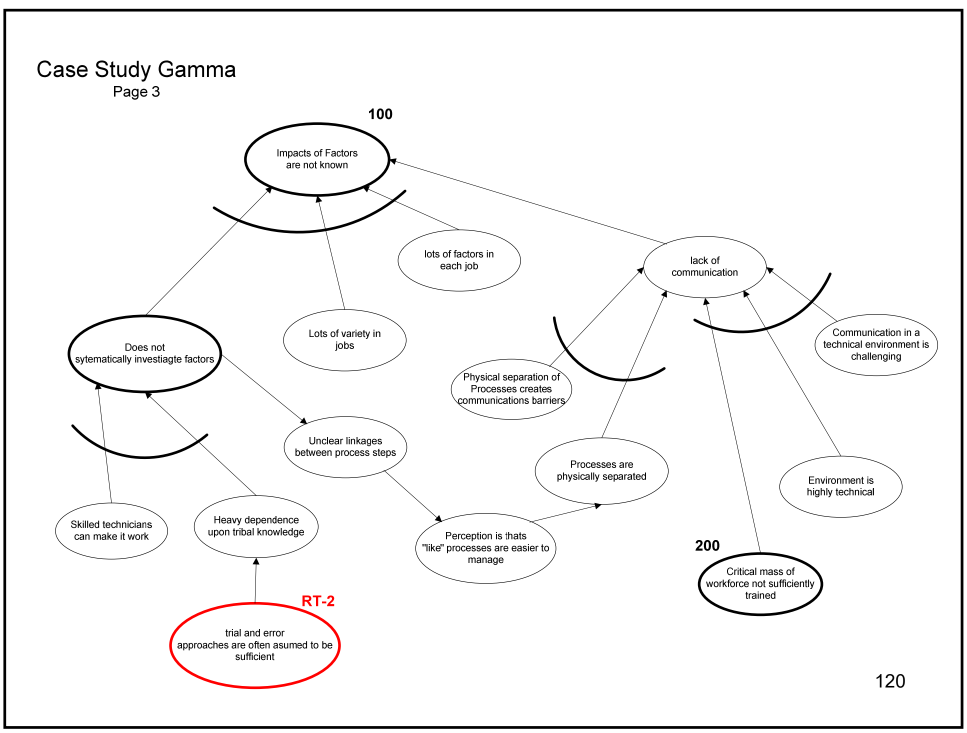
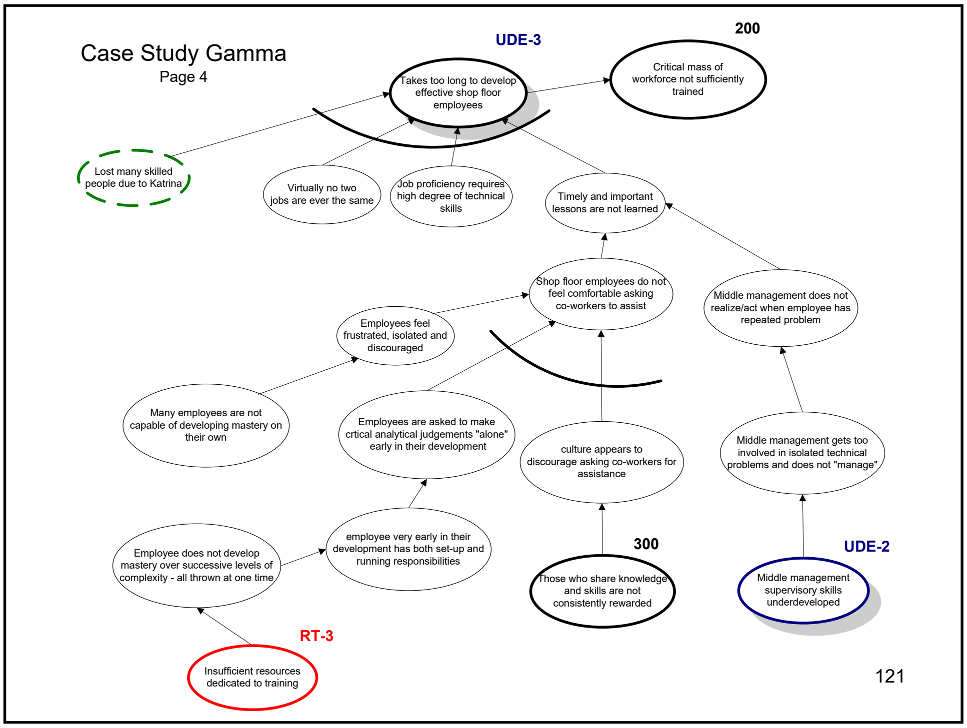
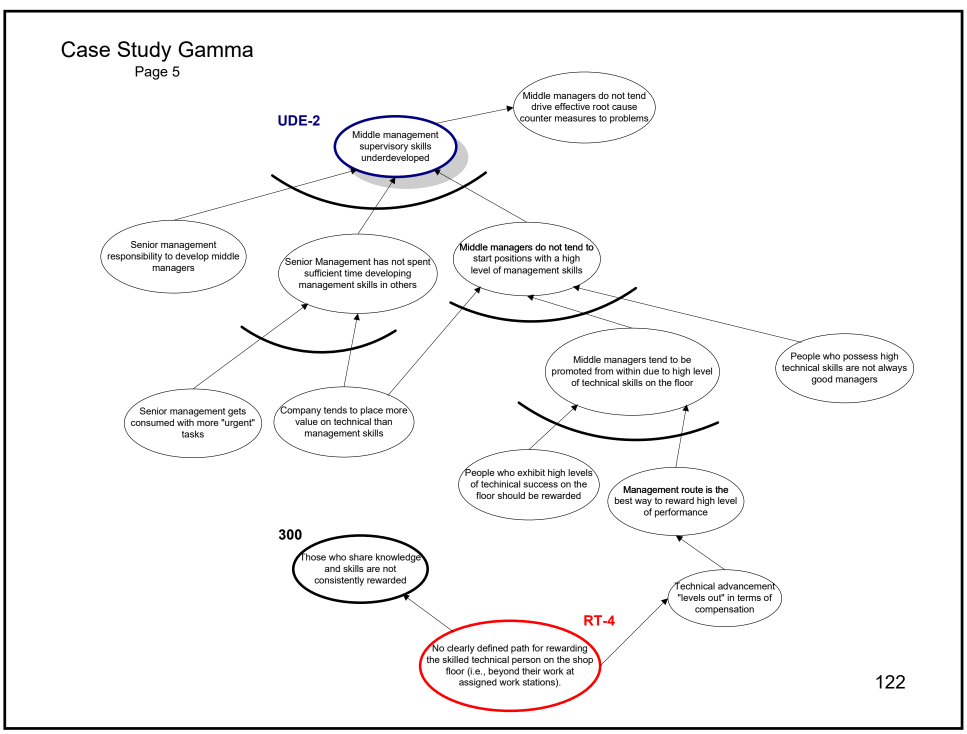

Case Study: Gamma
Page 2
UDE-1
Process Control is difficult to maintain
Right Factors are not consistently controlled
Production Methods Vary
Production Environment is complex
Standard work discipline not well established
Work standards not clearly documented
Proper work standards are not clearly known
100
Impacts of Factors are not known
Known good practices are not documented
longer, complex, and variable task times are more difficult to audit
task times are long, variable, and complex
Auditing is key to establishing daily work discipline
RT-1
200
Critical mass of workforce not sufficiently trained
Production pressures take away resources needed for documenting
Common understanding of production environment has not been established
documentation of std work requires resources
119


Case Study Gamma
Page 3
100
Impacts of Factors are not known
lots of factors in each job
lack of communication
Does not sytematically investiagte factors
Lots of variety in jobs
Communication in a technical environment is challenging
Physical separation of Processes creates communications barriers
Unclear linkages between process steps
Processes are physically separated
Environment is highly technical
Skilled technicians can make it work
Heavy dependence upon tribal knowledge
Perception is thats "like" processes are easier to manage
200
Critical mass of workforce not sufficiently trained
RT-2
trial and error approaches are often asumed to be sufficient
120


Case Study Gamma
Page 4
UDE-3
200
Takes too long to develop effective shop floor employees
Critical mass of workforce not sufficiently trained
Lost many skilled people due to Katrina
Virtually no two jobs are ever the same
Job proficiency requires high degree of technical skills
Timely and important lessons are not learned
Shop floor employees do not feel comfortable asking co-workers to assist
Middle management does not realize/act when employee has repeated problem
Employees feel frustrated, isolated and discouraged
Many employees are not capable of developing mastery on their own
Employees are asked to make crtical analytical judgements "alone" early in their development
culture appears to discourage asking co-workers for assistance
Middle management gets too involved in isolated technical problems and does not "manage"
employee very early in their development has both set-up and running responsibilities
Employee does not develop mastery over successive levels of complexity - all thrown at one time
300
Those who share knowledge and skills are not consistently rewarded
UDE-2
Middle management supervisory skills underdeveloped
RT-3
Insufficient resources dedicated to training
121


Case Study Gamma
Page 5
UDE-2
Middle management supervisory skills underdeveloped
Middle managers do not tend drive effective root cause counter measures to problems
Senior management responsibility to develop middle managers
Senior Management has not spent sufficient time developing management skills in others
Middle managers do not tend to start positions with a high level of management skills
Middle managers tend to be promoted from within due to high level of technical skills on the floor
People who possess high technical skills are not always good managers
Senior management gets consumed with more "urgent" tasks
Company tends to place more value on technical than management skills
People who exhibit high levels of techinical success on the floor should be rewarded
Management route is the best way to reward high level of performance
300
Those who share knowledge and skills are not consistently rewarded
Technical advancement "levels out" in terms of compensation
RT-4
No clearly defined path for rewarding the skilled technical person on the shop floor (i.e., beyond their work at assigned work stations).
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Case Study: Gamma

Case Gamma: Summary UDEs and Root Causes

UDEs	Root Causes
• **UDE-1:**. Process Control is difficult to maintain. • **UDE-2 :** Middle management supervisory skills are underdeveloped • **UDE-3:** Takes to long to develop effective shop floor employees. • **UDE-4:** Internal failure rate is too high. • **UDE-5:** Frequently customer due dates are missed.	• **RT-1:** Common understanding of production environment has not been established. • **RT-2:** Trial and error approaches are often assumed to be sufficient. • **RT-3:** Insufficient resources dedicated to training • **RT-4:** No clearly defined path for highly skilled technical people to add value beyond their isolated work on the shop floor.

Note: There is not a one-to-one relationship between the UDEs and the four root causes. The relationships are defined by the CRT.

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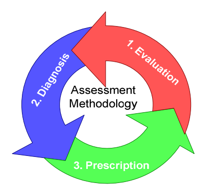
Case Study: Gamma



Prescription Stage

Objective: *develop a set of recommendations which target elimination of root causes identified during diagnosis. The recommendations are developed guided by appropriate elements selected from within the PST*

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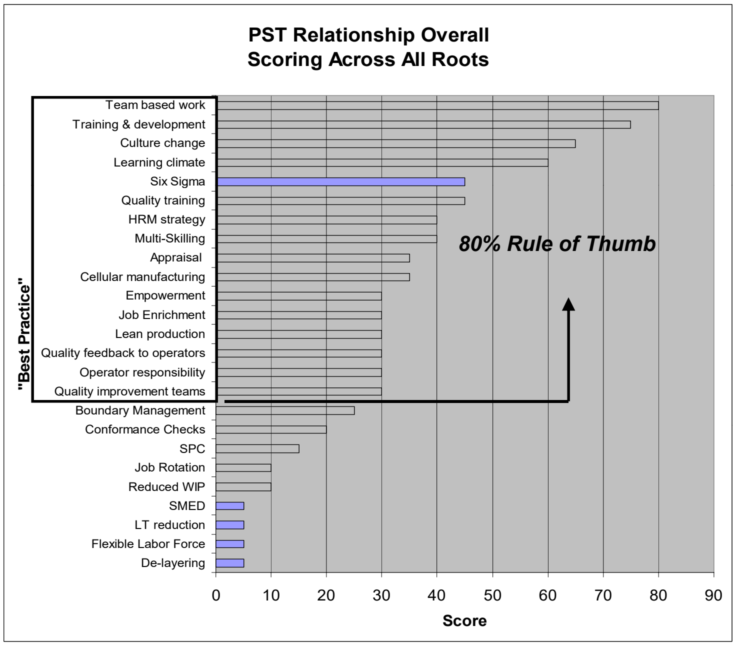
Case Study: Gamma



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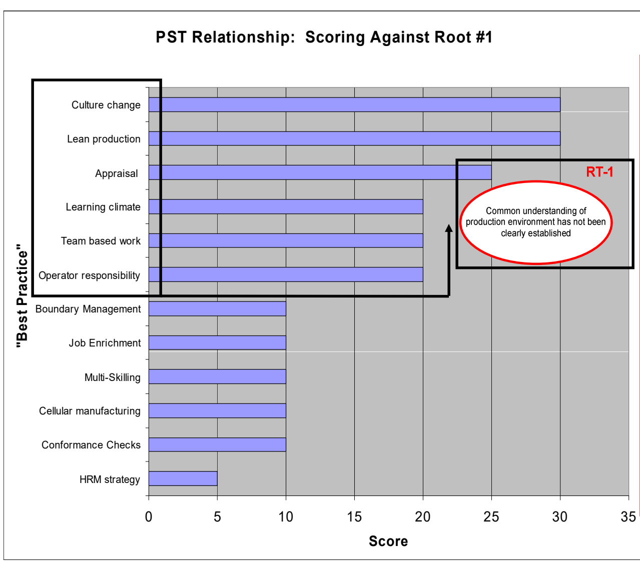
Case Study: Gamma

Recommendation #1



Recommendation #1

Establish a visual management program on the floor so that non-preferred conditions/methods are rapidly detected and corrected and preferred conditions/methods are clearly illustrated. This includes the use of such tools as 5S, one-point lessons, and "andon" indicators at the workstation to indicate current performance status in terms of both quality and throughput [e.g., red – immediate attention, yellow-danger, green-proceed]. Establish regular audit program to ensure compliance and effectiveness. Publicly track audit results so that progress toward a more visual shop floor is tracked more objectively.

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Case Study: Gamma

Linking PST Elements to Recommendation #1

Recommendation #1

Establish a visual management program **(4.B-1, 4.E-4)** on the floor so that non-preferred conditions/methods are rapidly detected **(1.E-4)** and corrected and preferred conditions/methods are clearly illustrated. This includes the use of such tools as 5S **(4.B-1)** one-point lessons **(4.E-5),** and "andon" indicators **(4.B-1)** at the workstation to indicate current performance status in terms of both quality and throughput [e.g., red – immediate attention, yellow-danger, green-proceed]. Establish regular audit program **(1.E-4)** to ensure compliance and effectiveness. Publicly track audit results so that progress toward a more visual shop floor is tracked **(3.A-2)** more objectively.

Prioritized PST Elements for Root #1

Ref #	PST Element
4.B-1	Lean production
4.E-4	Culture change
1.E-4	Appraisal
3.A-2	Operator responsibility
3.E-2	Team based work
4.E-5	Learning climate

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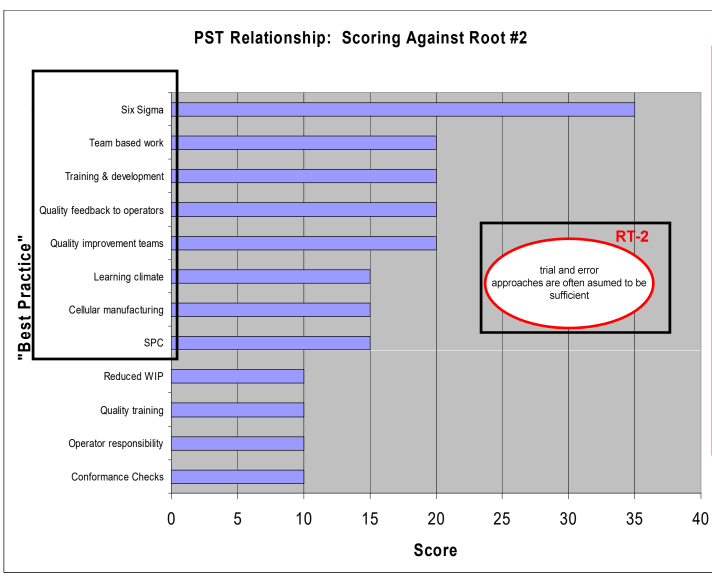
Case Study: Gamma

Recommendation #2



Recommendation #2

Accelerate transition away from functional layout toward a cellular layout in order to enhance communications between processes. Continue to apply DOE and other statistical tools to shed light on the effect of processes (e.g., milling) on downstream processes (e.g., polishing). Regularly review capability of the measurement system in terms of repeatability and reproducibility.

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Case Study: Gamma

Linking PST Elements to Recommendation #2

Recommendation #2

Accelerate transition away from functional layout toward a cellular layout **(3.C-3)** in order to enhance communications between processes **(3.A-1, 3.A-3, 3.E-2).** Continue to apply DOE and other statistical tools **(4.D-5, 1.E-5)** to shed light **(4.E-5)** on the effect of processes (e.g., milling) on downstream processes (e.g., polishing). Regularly review capability of the measurement system in terms of repeatability and reproducibility **(4.D-5).**

Prioritized PST Elements for Root #2

Ref #	PST Element
4.D-5	Six Sigma
3.A-1	Quality improvement teams
3.A-3	Quality feedback to operators
1.E-5	Training & development
3.E-2	Team based work
1.A-2	SPC
3.C-3	Cellular manufacturing
4.E-5	Learning climate

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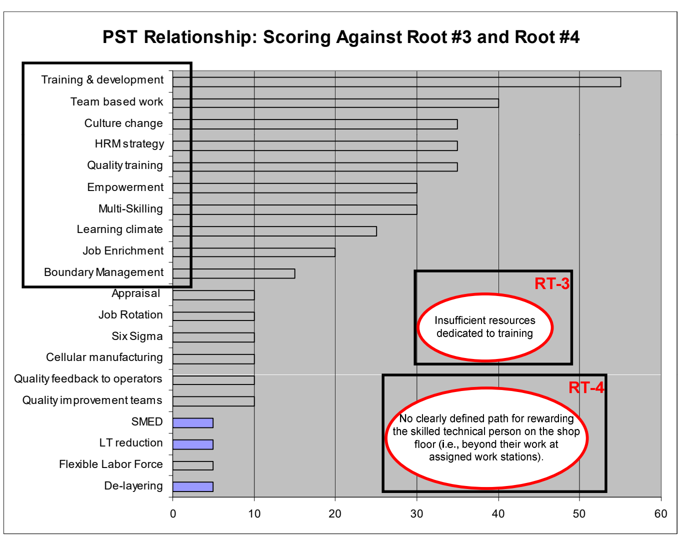
Case Study: Gamma

Recommendation #3



Recommendation #3

Develop a technical career path which encourages those that have attained a high level of mastery to share, mentor, and develop others. This provides a career growth opportunity outside of management in terms of mentoring other employees in developing greater skills. Establish "stair step" milestones so that employees can achieve intermediate levels of success. Consider classifying employees in terms of their ability to handle jobs of low-medium-high levels of difficulty and in terms of their skills at performing set-ups and process monitoring. Publicly track development of employees across development benchmarks.

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Case Study: Gamma

Linking PST Elements to Recommendation #3

Recommendation #3

Develop a technical career path **(4.E-1, 3.E-3)** which encourages those that have attained a high level of mastery to share, mentor, and develop others **(1.E-5, 3.E-2).** This provides a career growth opportunity outside of management in terms of mentoring other employees in developing greater skills **(1.E-2, 3.A-4).** Establish "stair step" milestones so that employees can achieve intermediate levels of success ***(4.E-5)***. Consider classifying employees in terms of their ability to handle jobs of low-medium-high levels of difficulty and in terms of their skills at performing set-ups and process monitoring. Publicly track development of employees across development benchmarks **(4.E-4)**.

Prioritized PST Elements for Root #3, #4

Ref #	Best Practice
1.E-5	Training & development
3.E-2	Team based work
3.A-4	Quality training
4.E-1	HRM strategy
4.E-4	Culture change
1.E-2	Multi-Skilling
4.E-2	Empowerment
4.E-5	Learning climate
3.E-3	Job Enrichment
3.E-4	Boundary Management

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Case Study: Gamma

Case Gamma: Mapping of PST Elements to Recommendations

Ref #	PST Element	Total Score (overall)	Cummulative Score	Rec_1	Rec_2	Rec_3
3.E-2	Team based work	80	10%		X	X
1.E-5	Training & development	75	19%		X	X
4.E-4	Culture change	65	28%	X		X
4.E-5	Learning climate	60	35%	X	X	X
3.A-4	Quality training	45	41%			X
4.D-5	Six Sigma	45	46%		X	
1.E-2	Multi-Skilling	40	51%			X
4.E-1	HRM strategy	40	56%			X
3.C-3	Cellular manufacturing	35	61%		X	
1.E-4	Appraisal	35	65%	X		
3.A-1	Quality improvement teams	30	69%		X	
3.A-2	Operator responsibility	30	73%	X		
3.A-3	Quality feedback to operators	30	76%		X	
4.B-1	Lean production	30	80%	X		
3.E-3	Job Enrichment	30	84%			X
4.E-2	Empowerment	30	88%			
3.E-4	Boundary Management	25	91%			
2.A-3	Conformance Checks	20	93%			
1.A-2	SPC	15	95%			
1.B-1	Reduced WIP	10	96%			
1.E-1	Job Rotation	10	98%			
3.B-2	De-layering	5	98%			
3.B-4	Flexible Labor Force	5	99%			
1.C-4	LT reduction	5	99%			
1.C-6	SMED	5	100%			
	Total	800				

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Case Study: Gamma

Transformation of UDEs into Recommendations

Undesirable Effects (UDEs)

- **UDE-1:** Process Control is difficult to maintain.
- **UDE-2:** Middle management supervisory skills are underdeveloped.
- **UDE-3:** Takes too long to develop effective shop floor employees.

Root Causes

- **RT-1:** Common understanding of desired production environment has not been established.
- **RT-2:** Trial and error approaches are often assumed to be sufficient.
- **RT-3:** Insufficient resources are dedicated to training.
- **RT-4:** No clearly defined path for highly skilled technical people to

apply DOE and other statistical tools to shed light on the effect of processes (e.g., milling) on downstream processes (e.g., polishing). Regularly review capability of the measurement system in terms of repeatability and reproducibility.

- **Rec_3:** Develop a technical career path which encourages those that have attained a high level of mastery to share, mentor, and develop others. This provides a career growth opportunity outside of management in terms of their mentoring other employees in developing greater skills. Establish "stair step" milestones so that employees can achieve intermediate levels of success. Consider classifying employees in terms of their ability to handle jobs of low-medium-high levels of difficulty and in terms of their skills at performing set-ups and process monitoring. Publicly track development of employees across development benchmarks.

4.E-1	HRM strategy
3.C-3	Cellular manufacturing
1.E-4	Appraisal
3.A-1	Quality improvement teams
3.A-2	Operator responsibility
3.A-3	Quality feedback to operators
4.B-1	Lean production
3.E-3	Job Enrichment

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TBAM Feedback: Client Receptivity

Client Gamma

Recommendation	Effectiveness *"The recommendation, if implemented, would have a substantially positive impact on the manufactring enterprise."* *Please rate each recommendation on a score of 1-5* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	Implementability *"The recommendation is practical and implementable without spending excessive time and resources."* *Please rate each recommendation on a score of 1-5* *Score 1: Strongly Disagree* *Score 5: Strongly Agree*	Overall Score
Rec_1:	4	3	7
Rec_2:	5	5	10
Rec_3:	5	5	10

General Comments
The assessment brought some things into focus and helped establish a stronger sense of the priorities. Overall this was worth the investment of time and resulted in recommendations which are both helpful and implementable. However, much additional work and thought is required in order to achieve desired results.
Would like to see a tighter connection between the best practice elements and the recommendations.

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Client Feedback

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