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A Systems-Based Framework for the Assessment of Performance Measurement System Implementations in R&D Organizations

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A SYSTEMS-BASED FRAMEWORK FOR THE ASSESSMENT OF PERFORMANCE MEASUREMENT SYSTEM IMPLEMENTATIONS IN R&D ORGANIZATIONS

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ABSTRACT

A SYSTEMS-BASED FRAMEWORK FOR THE ASSESSMENT OF PERFORMANCE MEASUREMENT SYSTEM IMPLEMENTATIONS IN R&D ORGANIZATIONS

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Performance measurement is utilized by organizations in all industries, including research and development (R&D). Measures are developed, data are collected, and the measurement results are used to drive the organization. The implicit hope is, of course, that the measures drive the organization to improve. However, literature identifies high failure rates directly related to performance measurement system (PMS) implementations. Establishing the fundamental operational characteristics associated with successful PMSs would provide a significant contribution towards the establishment of PMS assessment criteria. This research addresses this gap through the use of a grounded theory method employed to identify these operational characteristics, assesses the findings against systems theory concepts, and produces a practical assessment framework for R&D PMSs.

A grounded theory method was used to identify a theoretical construct of operational characteristics. These operational characteristics were then compared to systems theory axioms and principles to evaluate them in terms of systems complexity. These two steps provided a comprehensive basis for a systems-based assessment of R&D PMS implementations. Finally, the research introduces a framework for assessment, using maturity levels, as a practical contribution by aligning the theoretically-derived operational characteristics and an adaptation of the Capability Maturity Model. The

systems-based R&D PMS implementation assessment framework provides practitioners with a means to assess the current state of their PMS implementation and provides guidance needed for them to improve their PMS.

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NOMENCLATURE

COI	Critical Operational Issue
MOE	Measure of Effectiveness
MOP	Measure of Performance
SME	Subject Matter Expert
PMS	Performance Measurement System
R&D	Research and Development
IRB	Institutional Review Board

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CHAPTER 1

INTRODUCTION

Performance measurement has become a key evaluation process used in all industries, including research and development (R&D). It is done in large and small businesses, production and manufacturing, and public and private sectors. But why measure performance? Behn (2003) provides a succinct answer: we measure performance so that we can improve performance. Measures are developed, data are collected, and the measurement results are used to drive a company. The implicit hope is, of course, that the measures drive the company in a "positive" direction. Kaplan and Norton (1992) begin their seminal discussion on the Balanced Scorecard with "what you measure is what you get" (p. 71). The implication of this statement is significant. If a company has developed an effective set of measures, then the results of these measures will provide a valid snapshot of the state of the company. However, if the wrong measures are selected, if the measures are not balanced, if they have not been tailored to the company's objectives, or if they fail to operate holistically towards the company's true mission, then the process of measuring performance can be meaningless (Kaplan & Norton, 2007; Kerssens-van Dronglen & Cook, 1997; Neely, Platts, Richards, Gregory, & Bourne, 2000). A tool to assess a PMS implementation would be of use to determine its effectiveness. Therefore, this dissertation will develop a systems-based framework for the assessment of R&D performance measurement system implementations built from four streams of literature: performance measures for R&D, performance measurement systems (PMS), PMS assessment, and systems theory.

1.1 PERFORMANCE MEASUREMENT IN R&D

Although R&D has been "considered to be a unique, creative, and unstructured process that was difficult, if not impossible to control" (Kerssens-van Dronglen & Cook, 1997, p. 345) over the past two decades, the effectiveness of performance measurement systems for R&D systems has improved (Meyers & Hester, 2011). In R&D, the emergent nature of the work, along with the financial reward "time lag" inherent to the field, can lead to difficulty in creating effective measures. Traditional backward looking indicators, such as financial gauges, are not appropriate in an R&D context (Meyers & Hester, 2011). Issues differentiating performance measurement in R&D versus production industries, such as manufacturing, include difficulty in predicting the application of R&D projects and the extended time window R&D has before financial benefits can be realized. Automotive manufacturers may wait for two years between R&D work and first product sales, while lag times for Bell Laboratories' basic research projects are typically between seven and 19 years (Kerssens-van Dronglen & Cook, 1997). This creates a need for measures that differ from those in manufacturing and production environments. Measuring the number of products sold, return on investment, or cycle time cannot be done in a meaningful way in a short period of time in the R&D environment. These issues inherent to R&D lead to additional complexity in the implementation of a PMS.

1.2 PERFORMANCE MEASUREMENT SYSTEMS

While the Balanced Scorecard has become the most widely accepted performance measurement framework in use today (Neely et al., 2000), a universally accepted performance measurement system (PMS) does not exist. Frameworks such as the Balanced Scorecard (Kaplan & Norton, 2007) and the Performance Prism (Neely et al.,

2002) claim to provide holistic solutions, which consider multiple perspectives, claim to effectively develop performance measures when applied as intended. However, unsuccessful implementations of the Balanced Scorecard can occur when the its perspectives are blindly followed and allowed to constrain the PMS leading to "excessive, redundant or flawed measures that drive inappropriate behaviours" (Paranjape et al., 2006, p. 11). The value of the implementation of the PMS is dependent on the skill of the person or team correctly understanding the intentions of the PMS framework and their skill at developing the right measures. Ergo, creating a useful PMS may require technical assistance which may not always be available (Wholey & Newcomer, 1997). This is in agreement with Sproles' (2002) assertion that there is often confusion in the development of performance measures as a result of people confusing measures of performance (MOP), which identify how well a solution meets a specification, with measures of effectiveness (MOE), which identify how well a solution actually achieves its intended purpose. Therefore, while different organizations report varied levels of satisfaction with their PMS implementation, it appears that the lack of understanding of how to effectively design the PMS may be the root problem preventing the desired results.

1.3 PMS IMPLEMENTATION ASSESSMENT

Implementation of a PMS will vary between organizations (Tangen, 2005) and each will require that the setting within which the PMS will operate is well understood (Neely & Bourne, 2000). Neely (2000) asserts that many PMS frameworks provide little guidance on how the appropriate measures can be identified, introduced and ultimately used. The way in which the theoretical framework is applied will differ between organizations. The effectiveness of the PMS then becomes a function of the skill of the management team developing it and their ability to understand the complex social environment it must work effectively within. Two different organizational implementations, using the same performance measurement system framework, can yield very different results (Ho & McKay, 2002). This is not always "bad" in that both may be effective implementations. However, this ambiguity leads to the question of "how can we tell how we have done" in the implementation of a PMS? It is as if a group of young artists has been given the same paint-by-numbers canvas, but after each artist has painted the picture, differing skill levels are apparent and some pictures are more beautiful than the others. There will be variations in the effectiveness of different implementations. This suggests the need for assessment criteria for the PMS implementation. Assessment frameworks such as the Performance Measurement Questionnaire (Dixon, Nanni, & Volmann, 1990) and PMS Class Ranking System (Tangen, 2005) provide ways for organizations to decide if gaps exist in their PMS implementations or if their implementation is "mature" in the sense that it addresses information sharing and multiple perspectives. Although these assessment frameworks provide guidance in the assessment of PMS implementations, they were not explicitly developed from a systems-based approach or tailored specifically for the unique challenges of R&D performance measurement. The next section discusses the value of the systems approach as it relates to performance measurement in organizational settings.

1.4 SYSTEMS THEORY

Systems theory, along with its associated approach and principles, is useful when studying complex, socio-technical systems (Keating & Pyne, 2001) such as R&D

systems. The implementation of a PMS for an R&D system must effectively deal with the complexity of the system it is measuring. The natural, and intended, consequence of a PMS is that it will affect change in an organization. Bourne, Neely, Mills, and Platts (2003) argue that to affect change within an organization, both hard and soft system approaches are necessary. Hard system approaches are built under the premise that change can be achieved by logical and rational understanding of the current state and objectives of an organization while soft system approaches are built from the belief that organizational change can be best effected using social science techniques (Bourne et al., 2003). Many organizational systems that implement performance measurement systems are highly integrated and complex systems. Keating (2000) asserts that the PMS must work effectively in complex, socio-technical organizations, not the mechanistic classical view of "organizations as machines" (p. 181) and that soft system approaches are consitent with creating a systemic understanding of organziational complexity and the issues that surround it. Many authors have noted that the failure to address system complexity, multiple stakeholders, and human perspectives can lead to a failure to fully understand problems, and the consequences of change, in organizational systems (e.g., Behn, 2003; Kaplan & Norton, 2007; Kerssens-van Dronglen & Cook, 1997; Metawie & Gilman, 2005; Neely et al., 2002). For example, people within a system will often adjust their behaviors based on the measures and this cybernetic effect can have both desirable and undesirable outcomes (Hester, Baggett, Shauger, & Haynes, 2010). Scientists and engineers working on cutting edge technologies often have an aversion to "bean counting" processes and instead of buying into the PMS reporting process, they may look at the way measures have been developed and try to "game" the measurement process to gain a personal advantage such as more funding, higher pay, more technical support, etc. Metawie (2005) agrees, arguing that employees may look to game the system and maximize their benefits in response to performance indicators if their pay is tied to performance. This gaming response can lead to dysfunctional behavior with the employee neglecting other necessary duties for which their performance based pay is not properly tied. Allowing incentives tied to performance to be the dominant component in a PMS can be attractive to a manager as a decision tool. However, one cannot discount the need for a PMS to address systemic issues including information, communication, and alignment (Kaplan, 2008). A systems-based approach to PMS implementation evaluation will consider multiple perspectives and attributes essential to the identification of effective measures and seek to minimize inappropriate measures and their associated impacts within the system. Systems theory provides a foundation for problem framing in complex socio-technical environments and should be used when evaluating the issues surrounding PMS implementations.

A synthesis of four threads, performance measurement in R&D, Performance Measurement Systems, PMS assessment, and systems theory, has been gleaned from scholarly literature. Together, they provide the basis for development of the systems-based assessment criteria for R&D performance measurement system implementations pursued in this dissertation.

1.5 RESEARCH PURPOSE STATEMENT

The purpose of this study is to develop a systems-based framework for the assessment of performance measurement system implementations in R&D organizations. This framework is meant to be applied at the enterprise level by industry practitioners to assess their PMS implementation. For this dissertation, enterprise level denotes the organizational level responsible for and capable of making decisions and implementing them consistently throughout the company. The framework could be used to determine if an organization's performance measurement system is utilizing effective and appropriate indicators to lead to improved performance. Alternatively, application of the framework should identify inappropriate performance measures that do not provide value and/or may cause unintended consequences. The research will qualitatively study the commonalities in performance measures, and the related performance measurement systems, that are suggested in the literature to be applicable to R&D systems. A hypothesis of the study is that root generalities exist in R&D systems that will allow for development of the framework's assessment criteria for performance measurement systems at the enterprise level.

1.6 RESEARCH QUESTIONS

Questions have been established to clearly delineate the outputs of the study. These research questions are framed specifically to address the study's goal of developing a framework for the assessment of performance measurement systems for R&D organizations. Successfully addressing these questions will provide a bridge across the current gap in the literature.

The research shall answer the following questions:

1. What operational characteristics are necessary for an effective R&D performance measurement system at the enterprise level?
2. What systems theory concepts are relevant to the assessment of performance measurement systems in an R&D environment?

3. How can the effectiveness of R&D performance measurement system implementations be assessed from a systems perspective?

1.7 RESEARCH ASSUMPTIONS, LIMITATIONS, AND DELIMITATIONS

1.7.1 Assumptions. The goal of the research is to develop a systems-based framework for assessment of performance measurement system implementations in R&D organizations. As with any systems analysis effort, boundaries need to be established for the system to be evaluated. Part of the bounding process involves making certain assumptions. In the R&D context, some of these assumptions include:

- There exists a core set of functions that can be accepted as necessary for judging the effectiveness of R&D performance.
- An effective performance measurement assessment framework can be applied generically at the enterprise level to account for the unique aspects of different R&D organizations.
- The value of the performance measurement system assessment can be seen in a similar way by stakeholders. Agreement is necessary that the basis for assessment is valid prior to delivering results.
- Results from application of the framework may not be optimal for all stakeholders. Stakeholders will be willing to accept recommendations that may not be optimal for them as a subsystem of the larger complex system.
- Environmental factors, such as government regulation and influence, are sufficiently understood.

1.7.2 Limitations. The research will build a framework to assess PMS implementations in R&D organizations at the enterprise level. In spite of the wealth of literature available for guidance in PMS design, most PMS implementations fail (Neely & Bourne, 2000; Waal & Counet, 2009). Working with complex systems, such as PMSs, is often problematic in that there are multiple perspectives, human elements, and unknown system properties. Collecting data directly from organizations, in terms of their understanding and ideas surrounding R&D PMS implementation, was used to identify where the PMS implementation process could be broken down. This inductive approach strengthens validity and reliability by providing the opportunity for real life settings, rich descriptions, and triangulation. The following are limitations inherent to this methodology and the strategies used to mitigate them:

- Several participants were interviewed. However, there can still be non-representative cases or over-emphasis on unique cases. To mitigate this threat, a grounded theory methodology was followed and the research will utilize a minimum sample of five, and a maximum of fifteen, SMEs from regionally based R&D organizations in the interview process (as explained in 3.3.5). At least two R&D organizations from the public sector and two from the private sector were included. The associated coding process, detailed in Chapter 3, was used to identify themes in the interview responses. This provided a significant sample from which a grounded, thick description of the problem situation associated with the PMS implementations was built.
- Interviews were conducted using a representative sample of SMEs, defined in Chapter 3. The themes used to inform the assessment framework were based on a synthesis of the different individuals. SMEs may disagree on the results gleaned from the assessment framework and therefore SME feedback will not be used as a

basis for the study validity. The grounded theory methodology provided the basis for validity of the research.

- Funding in an R&D organization, especially public sector, is limited. This could prevent a thorough application of the assessment framework in practice. A partial application of this research's framework could produce misleading results. Application of the framework was not conducted as part of this dissertation. The validity of the assessment framework was derived from proper application of the grounded theory methodology.

1.7.3 Delimitations. Delimitation of the research allows the overall scope to be constrained so as to explain what the research does not intend to do (Leedy & Ormrod, 2010). Delimitations of this specific research effort included:

- Gender, age, and ethnicity of the participants will not be considered germane to the research questions. A finite number of participants were interviewed. A grounded theory methodology was followed and the research utilized five separate regionally based R&D organizations in the interview process. Seven interviews were conducted. Five interviews from the public sector and two from the private sector were included.
- The goal of the study has been to create a suitable means by which the strengths and weaknesses of R&D PMS implementations can be probed from a systems perspective. The specific systems principles used to accomplish this have been based a synthesis of principles from scholarly literature. All existing systems principles will not be used or required to create a necessary and sufficient lens through which to frame the thinking.

- Although PMS assessment may occur at many levels, the framework will be built for assessment of enterprise level performance measurement system implementations.
- The framework did not assess effectiveness of management in R&D organizations.
- The framework did not assess the usefulness of the R&D organization's area of interest.
- Context and environment are complex issues. There are certain worldviews that cannot be fully considered within the assessment framework.

1.8 SIGNIFICANCE OF THE RESEARCH

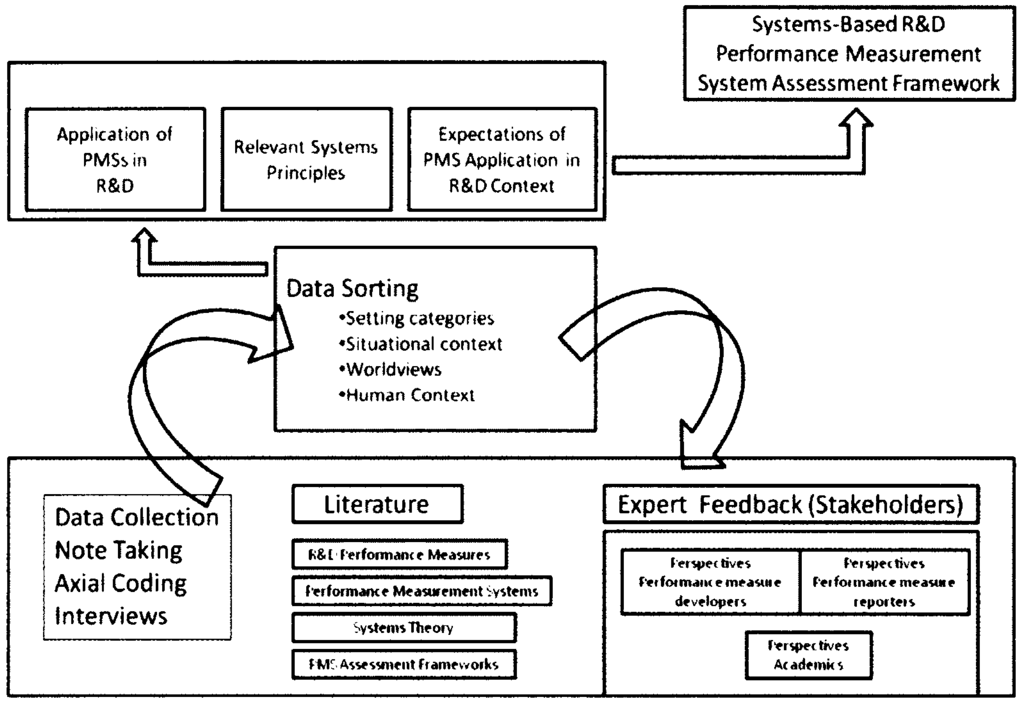
The research developed a holistic assessment criterion that can be used to analyze the implementation of performance measurement systems used by R&D organizations through a systems-based approach. The research created this assessment framework from the synthesis of scholarly literature in the areas of performance measurement, performance measurement systems, PMS assessment, and systems theory.

1.9 THEORETICAL, METHODOLOGICAL, AND PRACTICAL CONTRIBUTIONS OF THE RESEARCH

This research synthesized four threads: performance measurement in R&D, performance measurement systems, performance measurement assessment and systems theory. Currently, performance measurement is flooded with frameworks, many claiming to be holistic, balanced, and comprehensive (Kaplan & Norton, 1992; Lynch & Cross, 1991; Neely et al., 2002). Still, there has been no agreement on how a framework should be assessed in a functional setting (Neely et al., 2000). This study has developed the specific theoretical concepts, defined in this dissertation as operational characteristics, from a grounded theory method utilizing SME interviews and relevant academic literature to build a firm foundation for the PMS assessment paradigm. The operational characteristics were then aligned with systems theory to ensure they sufficiently cover the principles associated with real-world systems. It then built upon the foundation to develop a working framework to assess performance of implemented performance measurement systems for R&D organizations. This methodology has adopted and organized ideas from the current knowledge base while also identifying and addressing, when possible, problem limitations. This analysis will form the basis for a primary output of the study: an assessment criteria framework.

There is no literature that exists on systems-based R&D performance measurement system assessment frameworks or their application in practice. Information gained from expert critique has been used to validate or refute current scholarly state of the art and provide a point for iterative development of the subject area. As a practical and original contribution, leadership professionals from R&D settings were asked to review the assessment framework. Feedback from these subject matter experts (SMEs) has provided face validity to the research and opportunities for future improvements. Figure 1 shows an overview of the stages of development of the assessment framework.

Figure 1: Research Framework



Using information from the current state of the art, the R&D PMS assessment framework was synthesized from the grounded theory method and scholarly literature including performance measurement, performance measurement systems, systems theory, and R&D PMS implementation assessment. The following chapter reviews the literature, identifying key issues associated with R&D PMS assessment, and identifies the gaps that formed the basis for this dissertation's research questions.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews the current literature applicable to R&D performance measurement system assessment relevant to the research questions posed in the first chapter of this dissertation. The review further explores the areas discussed in the first chapter, performance measurement systems, performance measurement in R&D, PMS assessment and systems theory. Although there is a vast amount of literature on PMSs (Paranjape et al., 2006), significantly less has been found on the subject of PMS assessment. However, an exploration of the current state of the art on PMS assessment and how it may be applied to the R&D context is essential to this dissertation. Also, the subject of performance measurement in public and private sectors will also be reviewed to explore the concerns associated with these labels (Hester & Meyers, 2012). The chapter provides the basis for synthesis of the literature as applicable to R&D performance measurement system implementation assessment, but it must first begin with a review of performance measurement.

2.1 PERFORMANCE MEASUREMENT

Organizations understand that performance metrics can be utilized to provide a way to inform decision making and to assess and improve their business processes (Ojanen & Vuola, 2003). When designed appropriately, performance measures will provide a means to convey the organization's strategy throughout the system (Cocca & Alberti, 2010; Kaplan & Norton, 2007; Neely et al., 2000). It is now widely accepted that performance measures cannot be built from a single, backwards-looking accounting perspective (Bourne et al., 2003; Kaplan, 2008; Meyers & Hester, 2011), but instead must be built from a holistic perspective with an understanding of the measurements, purposes, stakeholder perspectives, organizational mission, and system context (Behn, 2003; Kerssens-van Dronglen & Cook, 1997; Neely et al., 2000; Ojanen & Vuola, 2003).

The literature identifies three terms foundational to organizational performance monitoring: performance measurement, performance measures, and performance measurement systems. Neely, Gregory, and Platts (2005) provide a set of definitions that are useful in discussion about the measuring of performance:

> *Performance Measurement*: The process of quantifying the efficiency and effectiveness of action
>
> *Performance Measure*: A metric used to quantify the efficiency and/or effectiveness of an action
>
> *Performance Measurement System*: The set of metrics used to quantify both the efficiency and effectiveness of actions (p. 1229)

These are tied together in that a performance measurement system must have appropriately developed metrics and processes associated with the quantification of actions. These areas together allow for informed decisions to be made as a result of analysis and interpretation of the performance measurement data(Cocca & Alberti, 2010). This leads one to question what decisions an organization may make once it is able to analyze performance measurement data. The next section discusses the purpose behind an organization's performance measurements.

2.1.1 Performance measurement's purpose. Behn (2003) proposes a set of eight purposes public managers have for measuring performance: (1) evaluate, (2) control, (3) budget, (4) motivate, (5) promote, (6) celebrate, (7) learn and (8) improve, as shown in Table 1. He points out that "the public manager's real purpose – indeed, the only real purpose – is to improve performance. The other seven purposes are simply a means for achieving this ultimate purpose" (Behn, 2003, p. 588).

Table 1: Eight purposes that public managers have for measuring performance (adapted from Behn, 2003, p. 588)

The Purpose	The public manager's question that the performance measure can help answer
Evaluate	How well is my public agency performing?
Control	How can I ensure that my subordinates are doing the right thing?
Budget	On what programs, people, or projects should my agency spend the public's money?
Motivate	How can I motivate line staff, middle managers, nonprofit and for-profit collaborators, stakeholders, and citizens to do the things necessary to improve performance?
Promote	How can I convince political superiors, legislators, stakeholders, journalists, and citizens that my agency is doing a good job?
Celebrate	What accomplishments are worthy of the important organizational ritual of celebrating success?
Learn	Why is what working or not working?
Improve	What exactly should who do differently to improve performance?

Effective performance measures must be derived holistically and capture both the relevant financial and nonfinancial data that steers a company toward its desired outcomes (Bremser & Barsky, 2004; Harty, 1999; Kaplan & Norton, 2007). The literature provides a number of ways that a well established set of performance measures will benefit a company. These include:

1. Improving stakeholder confidence by providing accountability (Metawie & Gilman, 2005; Neely et al., 2000; Wholey & Newcomer, 1997).

2. Increasing transparency (Wholey & Newcomer, 1997).
3. Providing defined goals and scopes for projects, allowing for more concrete design, planning, and implementation (Paparone & Crupi, 2006).
4. Providing very specific success criteria for projects (Paparone & Crupi, 2006).
5. Having the psychological value of reducing anxiety in the face of uncertainty by providing the assumption of control and predictability (Paparone & Crupi, 2006).
6. To increase efficiency and productivity (Harty, 1999).
7. Defining what "effectiveness" constitutes(Sproles, 2002).
8. Providing data for decision making (Kerssens-van Dronglen & Cook, 1997).
9. Allowing outcomes to be assessed at the end of implementation (Paparone & Crupi, 2006).

These identified benefits provide tangible reasons for purposefully measuring performance. Alternatively, picking the wrong measures, not balancing measures across different perspectives, or failing to take a systemic view of performance measurement with a system's context can result in the process of measuring performance being meaningless (Kaplan & Norton, 2007; Kerssens-van Dronglen & Cook, 1997; Neely et al., 2000). Paparone and Crupi (2006) provide a number of downfalls that can be associated with misguided implementation and/or analysis of performance measurement, as shown in Table 2.

Table 2: Shortfalls associated with performance measurement
(adapted from Paparone & Crupi, 2006, pp. 2-3)

1	Unconsciously adopting a paralysis-by-analysis mentality at the expense of a learn-by-doing mentality
2	Confusing quantitative knowledge with the quality of wisdom
3	Making linear assumptions of causality vice appreciating the complex, interactive, dynamic patterns of causality.
4	Jumping to implementation of solutions without taking time to understand an ever-changing problem as a continuous process.
5	Assuming that by breaking down the system into measurable segments or by deconstructing the processes within, the sum of the parts will equal a measure of the whole.
6	Failing to consider other process options because one has selected measures for the process in use.
7	Reinforcing one's cultural penchant for low-cost and high-speed measuring versus appreciating the richness and quality of observing and experiencing the actual activities in progress (in other words, failing to recognize that the numbers don't prescribe what to do next, people do).

So, while there are good and necessary reasons for measuring performance, there can be negative consequences associated with the development and interpretation of performance measures if done incorrectly. Further, picking the wrong metrics can cause unintended behaviors and lead an organization's focus away from the real issues (Metawie & Gilman, 2005; Neely & Bourne, 2000; Paparone & Crupi, 2006). Neely (2000) provides an example that describes how performance measurement can lead to unintended consequences:

In call centres, where the average time taken to answer the phone is used as a key measure, it is easy to find operators making lines ring busy when they are heavily loaded, imply to avoid particular calls being noted as unanswered within the target time. Alternatively, operators pick up phones and put them back down *again without ever speaking to the person at the other end, just to ensure that the call is answered within seven rings.* (p. 5)

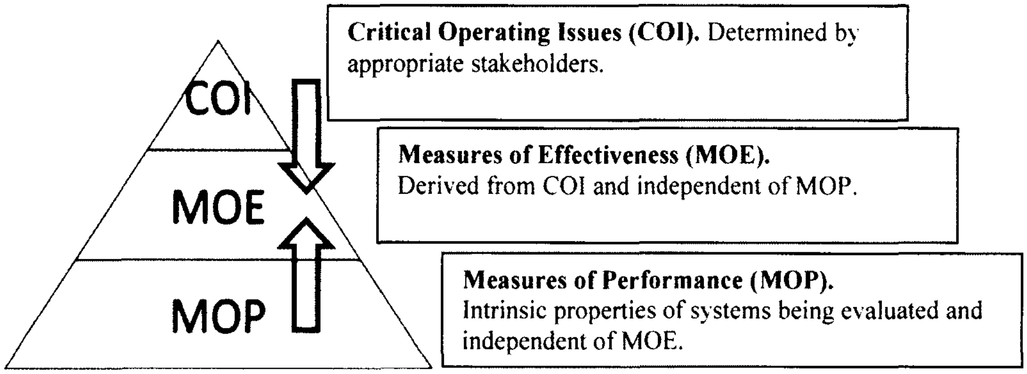
This example exemplifies how measures can cause dysfunctional behaviors in people which create a source of misleading data. It also illustrates how the process of performance measurement must take into account system complexity, such as the human-component to be sure that the PMS performs as intended. Significant literature exists providing the blueprints for successful implementation of performance metrics and measurement in R&D, such as those associated with operational test and evaluation, in the hopes of improving the art of performance measurement.

2.1.2 Operational Test & Evaluation. The objective of Operational Test and Evaluation (OT&E) is to determine how a system is performing under its most current realistic operational state (Stevens, 1979). Concepts from the OT&E area provide conventions to guide thinking in the development of effective performance measures in realistic setting independent of public and private sector designation and that the "test, or measurement, objectives clearly relate to organizational improvement, purposes, and operational context" (Hester & Meyers, 2012, p. 6) .

The concepts associated with OT&E, while not R&D-centric, are appropriate for thinking about performance measurement in R&D organizations. OT&E concepts include critical operational issues (COIs), measures of effectiveness (MOEs) and measures of performance (MOPs). These concepts are interconnected such that the ultimate performance measures are appropriately tied to the needs of the relevant stakeholders (Meyers & Hester, 2011; Sproles, 2002).

Meyers & Hester (2011) build from Sydenham (2003) to depict the structural relationship between COI, MOE and MOP shown in Figure 2.

Figure 2: Measurement conventions of Operational Test and Evaluation
(adapated from Meyers & Hester, 2011, p. 298)



Each of these concepts is elaborated in the following sections.

2.1.2.1 Critical operational issues. Critical Operational Issues (COIs) are the issues that are fundamental to a problem and, for the issue to be satisfied, must be addressed in an acceptable way. COIs are what Sproles (2002) calls the "show stoppers" (p. 256) or the emergent properties required by a system to perform its function. These are the issues that must be addressed for the system to be effective. Meyers and Hester (2011) provide an example of a COI. Fans of a baseball team may require a "championship caliber" team for them to feel as if their needs were met effectively. Anything less would be construed as a failure. This would lead to a COI for "championship caliber play." Sproles (2002) points out that other issues that some may consider "show stoppers", such as safety issues, may not actually be a necessary COI. He cites the Japanese Zero fighters which chose to maximize manuverability by sacrificing safety features such as armor for the pilots and self sealing fuel tanks. A though the fighter could be destroyed by a small amount of fire, it was extremely effective at winning battles by delivering the knockout blow while making the opponents miss.

2.1.2.2 Measures of effectiveness. Measures of effectiveness (MOEs) are use to determine how well, from the view of the stakeholder, something achieves its purpose (Sproles, 2001). Sproles (2002) defines MOEs as:

> *"the standards against which the capability of a solution to meet the needs of a problem may be judged. The standards are specific properties that any potential solution must exhibit to some extent. MOEs are independent of any solution and do not specify performance or criteria"*(p. 254)

Smith and Clark (2006) assert that specific performance measures for one system may not be appropriate for the measurement of another system despite the system's effectiveness. The author of this dissertation accepts this view point which is aligned with Sproles (2001, 2002), Meyers and Hester (2011) and Smith and Clark (2004, 2006). Smith and Clark (2006) further assert that the goal when working with MOEs is not to establish absolute measures, but rather to develop measures which can be used to rank one system against another. Smith and Clark (2004) offer a definition of an MOE as:

> *A measure of the ability of a system to meet its specified needs (or requirements) from a particular viewpoint(s). This measure may be quantitative or qualitative and it allows comparable systems to be ranked. These effectiveness measures are defined in the problem-space. Implicit in the meeting of problem requirements is that threshold values must be exceeded. (p. 3)*

Using the aforementioned definition and information from the literature, Smith and Clark (2006) establish five properties that can form the framework for comparison between systems. Therefore, MOEs should display the following characteristics:

1. The measure needs to increase as effectiveness increases (not all weighted sums will do this).
2. The measure needs to be bounded above by an ideal system and bounded

below by zero for non-compliance.

3. To manage complexity and allow for system decomposition, any measure needs to represent and support system decomposition and aggregation (for equivalent systems aggregate measures must be equivalent regardless of level of decomposition).
4. To facilitate comparisons between systems (which may have different internal characteristics and differing primary purposes) it is necessary to normalize the final effectiveness scores. The range [0, 1] is chosen (with 0 denoting an ineffective system and 1 denoting a perfectly effective system).
5. Ideally the measures should be ratio scales which means that they have a natural zero point and numbers which are multiples of each other directly indicate their value. (For example, a system with an effectiveness measure of 0.8 is twice as effectiveness as a system with a measure of 0.4). Ratio scales directly support the achievement of properties 1 to 4.

(Smith & Clark, 2006, p. 7)

These properties should be used to choose amongst alternative approaches to defining MOEs. Smith and Clark (2006) go on to discuss mathematical frameworks that fit the requirements of the above properties for measuring effectiveness. These include decision analysis approaches such as Multi-Attribute Utility Theory (MAUT), which aligns with work done by Meyers and Hester (2011), and which is appropriate for decision problems where measures can be scaled to reside between 0 and 1.

2.1.2.3 Measures of performance. Smith and Clark (2006) note that Measures of Effectiveness (MOEs) are associated with the problem domain (what are we trying to achieve) whereas Measures of Performance (MOPs) are associated with the solution domain (how are we solving the problem). MOPs are selected such that they should satisfy the emergent properties of the MOEs (Sproles, 2002). Further, MOPs are based on a system's internal view point rather than the external view, such as the views of stakeholders, which are associated with MOEs. Meyers and Hester (2011) derive a definition for MOPs from the literature provided by Sproles (2000, 2001, 2002):

> *Measures of performance are evaluations of systems' intrinsic functions by which can be judged, using MOEs, those systems' capabilities to resolve the needs from which the MOE and their antecedent COI derived.* (p. 5)

Put more simply, MOPs are the specific output measures of a system (Meyers & Hester, 2011). Sproles (2000) provides an example that helps to distinguish between MOEs and MOPs. If one considers cleaning up a river, specific measures such as "suspended solids removed, percentage reduction in heavy metals, reduction in volume of industrial liquid waste, etc" (p. 57) would be MOPs while the MOEs would be concerned with the outcomes associated with a solutions implementation such as "furthest distance upstream fish of type X have been positively identified" (p. 57).

This section described the way an organization can establish and differentiate between COIs, MOEs, and MOPs when developing performance measures. As stated earlier, these measures are appropriate in multiple contexts including the R&D context. However, R&D performance measurement offers distinct challenges. The following section discusses the similarities and differences of R&D performance measurement with that of other organizations, such as production or manufacturing.

2.1.3 Performance Measurement in R&D. Several studies have been reviewed with respect to performance measurement of R&D activities. This section of the dissertation will concentrate on organizing and structuring information found in the literature concerning the metrics and evaluation methods associated with R&D performance measurement as well as the R&D function itself. Kerssens-van Drongelen and Bilderbeck (1999) offer the following explanation of the R&D function, which the author adopts for this discussion:

> *The objective of the R&D function is to successfully initiate, coordinate and accomplish the technology process and product activities of a company.* (p. 36)

The similarities and differences between R&D and traditional performance measurement, such as those found in production and manufacturing will also be discussed (Meyers & Hester, 2011; Neely et al., 2000).

Many of today's companies have determined that research and development is a requirement for long-term competitive advantage (Bremser & Barsky, 2004). In the past, R&D was thought of as an unstructured and artistic process that would be inhibited in a system that attempted to control its performance (Kerssens-van Drongelen & Bilderbeck, 1999). However, modern business processes expect that R&D must be accountable to the business in terms of efficiency, effectiveness, and strategic alignment with customer needs and the business mission (Kumpe & Bolwijn, 1994). It is now accepted that R&D operations cannot be considered as independent and isolated activities but instead must be seen as a critical component of a company's execution of strategy (Kerssens-van Drongelen & Bilderbeck, 1999; Pearson & Kerssens-van Drongelen, 2000).

Because performance measures are seen as a critical requirement for effective R&D performance (Pearson & Kerssens-van Drongelen, 2000), there is a need for effective implementation of R&D performance measures. There have been strides in the area of R&D performance measurement, building on the strategies of the Balanced Scorecard (Kaplan & Norton, 2007; Kerssens-van Dronglen & Cook, 1997), which provide improved techniques to understand R&D system effectiveness (Meyers & Hester, 2011). Although the last decade has seen an increasing amount of literature on R&D measurement, a universally accepted set of R&D measures still does not exist (Ojanen & Vuola, 2003) and there is no current consensus on the state of measurement knowledge specific to performance measurement in R&D. As previously stated, R&D was once considered a "unique, creative, and unstructured process that was difficult, if not impossible, to manage and control" (Kerssens-van Dronglen & Cook, 1997, p. 345), but now it is seen as a vital component in the execution of an organization's overall strategy (Bremser & Barsky, 2004). Because of this, it is reasonable to believe that organizations want to have effective R&D performance measures in place to monitor the R&D function as they do with any important component within an organization. Creating effective performance measures for R&D requires that one understands exactly what it is that makes R&D measurement unique.

2.1.4 Why is R&D Measurement Unique? Several authors point out differences that exist between performance measures in R&D and those found in production and manufacturing environments. Szakonyi (1994b) notes that a problem plaguing managers in the R&D environment is that, when measures are put in place to measure R&D output, they tend to focus on the quantitative aspects such as the number of patents or published papers. These indicators may help show that work is being done, but it does little to tie the work into R&D outputs or the organization's long term effectiveness or profitability.

Financial indicators are also used to evaluate R&D. However, many financial indicators are inappropriate in R&D environments because they can lead to a short term focus that doesn't support the organization's long term strategy (Hester & Meyers, 2011; Metawie & Gilman, 2005; Neely et al., 2005). While financial indicators may help to provide some insight into the R&D contribution to an organization's output, these measures simply cannot adequately address the quality or appropriateness of the R&D contribution with respect to an organization's mission and strategy (Szakonyi, 1994a). These aspects of R&D have made performance measurement in the field extremely difficult to measure and control (Kerssens-van Dronglen & Cook, 1997; Ojanen & Vuola, 2003) and have led to a preclusion of any widely accepted set of R&D performance measures (Ojanen & Vuola, 2003; Szakonyi, 1994b).

Most authors agree that an effective PMS for R&D must be tailored to the system context (Behn, 2003; Cocca & Alberti, 2010; Hester & Meyers, 2011; Kaplan, 2008; Kleingeld, Van Tuijl, & Algera, 2004; Neely et al., 2002; Ojanen & Vuola, 2003; Scott, 2005). For example, Kaplan (2008) notes that the value of an investment banker at Goldman Sachs may be in his or her ability to both have an expertise in financial products and maintaining relationships with valuable clients, although the value of this same employee may be totally different in the context of an online investment company like etrade.com. This holds true in the R&D context. If an R&D system struggles to have people with the right skills in place for a new R&D initiative or employees don't understand how to develop practical ideas in the context of the systems mission, funding, timeframes, etc., then the effectiveness of the R&D system will suffer (Szakonyi, 1994b).

2.1.5 R&D Performance Metrics. Several evaluation metrics for R&D performance have been established in the literature over the last several years. For example, Szakonyi (1994a; 1994b) suggests the following metrics for assessment of R&D activities:

- Selecting R&D
- Planning and managing projects
- Generating new product ideas
- Maintaining the quality of R&D process and methods
- Motivating technical people
- Establishing cross-disciplinary teams
- Coordinating R&D and marketing
- Transferring technology to manufacturing
- Fostering collaboration between R&D and finance
- Linking R&D to business planning

These ideas provide valuable areas that should be considered for monitoring performance and they are built around a benchmarking foundation in which a project or system is expected to compare themselves against an average (Szakonyi, 1994b). However, this assumes that the context of different groups are similar, which may not be true for all.

Similarly, Brown and Gobeli (1992) present a framework for productivity assessment using qualitative and quantitative measures. While they identify a number of indicators, they admit that balancing subjective, qualitative measures with structured, quantitative measures is difficult. They also argue that the time required to conduct qualitative interviews makes the process difficult to use on a regular basis. Therefore, they propose a "Top Ten" set of R&D productivity indicators that can be used regularly to keep a pulse on the state of the system (shown in Table 3).

This framework provides a template with specifications for quantitative assessment for R&D systems, but it falls short of providing a framework for analysis of the R&D industry, such as basic research, especially those that do not produce sales-related outputs. Further, neither case decomposes the assessment framework into MOEs and MOPs relevant to R&D assessment or describes how to tie the performance measures to the organization's vision and mission.

Table 3: Framework for productivity assessment
(adapted from Brown & Gobeli, 1992, p. 330)

Resources	% key skill areas learned by R & D personnel
Project Management	% technical specifications met or exceeded, averaged across completions
	% completion dates met or exceeded
People Management	% fully satisfactory or above R & D personnel resigning per year
Planning	Number of engineering change orders due to specification changes before product release
New Technology Study and Development	Number of patents/total number of R & D employees
Outputs	Number of complaints per product per year, averaged across project, with a three-month rolling average
Division Results / Outcomes	% Sales from products released within the last three years
	Score on annual R&D scorecard survey, completed by marketing
	Annual sales/total R & D budget

Ojanen and Vuola (2003) recognized that many of the existing R&D PMS frameworks were built using a particular worldview. After compiling the data on the frameworks, they were able to decompose and categorize the differences and they identified several R&D measurement dimensions existing in the literature. Ojanen and Vuola (2003) suggest that the basic dimensions for R&D performance measurement fall into five categories:

1. **Measurement perspectives** – from whose perspective is the measurement taken?
2. **Measurement purpose** – the measurement's purpose must be identified to make the measurement useful.
3. **Level of measurement** – measurements must be appropriate to the level at which they implemented project, company, team, individual etc.
4. **R&D type** – Measurement techniques (quantitative, qualitative, semi-qualitative) should be tailored to the type of R&D activity.
5. **Process phase** – R&D can be treated as a processing system with inputs (people, information, ideas, funds, etc.), outputs (publications, new products, new knowledge, etc) and outcomes (cost reductions, sales, product improvements). (adapted from: Ojanen & Vuola, 2003)

Table 4 presents the complete list of category types associated with each measurement dimension. Again, these categories are derived from the literature. For example, the measurement perspectives dimension considers categories assembled from the Balanced Scorecard (Kaplan & Norton, 1992) and the process phase dimension considers categories found in Brown and Gobeli's (1992) productivity framework. It also aligns with the dimensional approach to public and private sector measurement (Hester & Meyers, 2012) detailed previously.

Although the work found in the literature on performance measurement does provide a starting point from which the assessment framework can be built from, the work to date has provided a "blueprint" for success while the requirement for an assessment framework is needed to build the framework for the "final inspection" of the implementation. Another consideration is that R&D organizations commonly exist in both the public and private sector. A review of the different opinions found in the literature follows to determine, in part, if a framework suitable for R&D PMS implementation assessment can be built to address differences in both contexts.

Table 4: Dimensions of R&D performance analysis
(adapted from Ojanen & Vuola, 2003, p. 16)

Measurement perspectives	The purpose of measurement	Measurement level	R&D type	Process phase
Customer	Strategic Control	Industry	Basic Research	
Internal	Justification of existence	Network	Exploratory research	In-Process
Financial, stakeholders	Benchmarking	Company	Applied research	Output
Other stakeholders	Resource allocation	SBU / department	Product development	Outcome
Learning	Development of activities / problem areas	Process	Product improvements (incremental)	
Etc.	Motivation, rewarding	Project		
	Etc.	Team		
		Individual		

2.1.6 Performance Measurement in Public and Private Sectors. A universal perspective does not currently exist in the literature pertaining to performance measurement in the public sector, which is funded through public tax dollars, and the private sector, which is funded through sales or some other form of private support (Hester & Meyers, 2012). Some literature asserts that public and private sector organizations can be thought of as fundamentally similar while others view it as fundamentally different. The obvious difference is that the ultimate goal of a private sector company is to generate a financial return on investment for its shareholders (Boland & Fowler, 2000). This distinction has been noted in the literature by several authors as a possible problem for measuring performance in public sector organizations (Boland & Fowler, 2000; Bremser & Barsky, 2004; Keating, Hester, Kady, & Calida, 2009; Kerssens-van Drongelen & Bilderbeck, 1999). However, other literature notes that drawing a line in the sand between private and public sector enterprise in terms of measuring performance may not be an essential requirement. Knott (1993) asserts that viewing management of public sector enterprise as hopelessly inefficient as a result of constantly changing political goals is an unwarranted stereotype. He argues further that private sector organizations often share similarities with the public sector such as similarities in management structure and government regulations that are often imposed on private industry. Bozeman and Bretschnieder (1994) assert that drawing a fundamental distinction between private and public sectors is flawed and instead propose that organizations be characterized by their degree of "publicness" or degree to which they are affected by "externally imposed political authority" (p. 202) regardless of their public or private designation.

These viewpoints fit within three approaches found in the literature: the generic, core, and dimensional approaches developed by Bozeman and Bretschnieder (1994) and Scott and Falcone (1998). Hester and Meyers (2012) capture these three different approaches comparing public and private organizations. They offer the definitions of these approaches as:

1. *The "**generic**" approach: This approach downplays the significance between the public and private sectors.*
2. *The "**core**" approach: This approach espouses fundamental distinctions between the public and private sectors.*
3. *The "**dimensional**" approach: This approach distinguishes organizations based on a number of dimensions that are independent of organizational sector* (p. 184)

Many similarities exist between public and private sectors that suggest a singular framework for assessment of performance measurement systems for both may be appropriate. The dimensional approach offers a means by which to group public and private organizations while not ignoring criteria that are associated with different degrees of political authority. For example, both public and private organizations look for effective ways in which to measure their performance to demonstrate their effectiveness and accountability to their relevant stakeholders (Northcutt & Taulapapa, 2012). These similarities hold true for the R&D paradigm too. For example, in both the public and private sectors, R&D performance measures should help drive the long term strategies and financial objectives of the organization (Bremser & Barsky, 2004). In private sector R&D, the performance measurement may center around financial Return on Investment

(ROI). Return on mission (ROM) has been suggested as a more appropriate measure to reflect the goal of the measurement for public sector R&D (Keating et al., 2009). Using ROM indicates that increasing mission performance is the primary goal and is a more accurate description for what is required in the public sector R&D arena. With this, even though the challenges in public sector R&D are unique, the idea of measurement between the public and private sectors, both based on a return, may be able to be seen in a similar way. Therefore, it seems that the degree to which public and private sector organizations are affected by political factors may be a more appropriate distinction when assessing an organization's PMS implementation.

The author of this dissertation believes that the dimensional approach best captures the way in which public and private sectors should be viewed with respect to performance measurement. This view is aligned with Hester and Meyers (2012), who state "public and private enterprise performance can and should be commonly measured" (p. 186) and Sheehan (1996) who states that performance measures should be based on mission so as to provide a foundation for a well-developed organization. Lastly, a study by Scott and Falcone (1998) statistically compared the utility of the three approaches over 900 R&D organizations and found that some core differences exist between public and private sectors, however, there still exists utility in the dimensional approach applied to the two areas. Instead of assuming that core differences preclude the development of a unified assessment framework for PMS implementations in R&D organizations, embracing the dimensional approach may provide a means to create a framework that can apply to both the public and private sector and will be the approach used in this dissertation.

This section has identified what the idea of performance measurement constitutes and how one may utilize the field of operational test and evaluation to guide the design and selection of performance measures. As noted, performance measures are ultimately expected to drive organizational improvement (Behn, 2003). Conversely, picking the wrong measures can lead to unintended consequences and dysfunctional behaviors (Metawie & Gilman, 2005; Neely & Bourne, 2000; Paparone & Crupi, 2006). It was also discussed how utilizing a dimensional approach to public and private sector performance measurement may be appropriate. The following section reviews how these areas are utilized within performance measurement systems. Different PMSs are evaluated to establish a basis for understanding the goals associated with them. Although many PMSs claim to be built holistically (e.g., Kaplan & Norton, 2007; Lynch & Cross, 1991; Neely et al., 2002), there are still different viewpoints that have driven their creation. Goals, commonalities, and differences between PMSs will inform the R&D PMS assessment framework.

2.2 PERFORMANCE MEASUREMENT SYSTEMS

Performance measurement system frameworks are used to guide the development of effective performance measures. A well designed system will inform the creation of measures that will steer an organization towards its most relevant goal: improvement (Behn, 2003). An effective PMS must be designed such that controls are established to ensure that the "combined efforts of the people involved, using multiple resources, are in line with company objectives and plans" (Kerssens-van Dronglen & Cook, 1997, p. 346). Establishing controls to provide long term improvement in R&D organizations is not any easy task. Many of the traditional financial indicators that center on accounting principles such as "Return on Investment" and "Earnings per Share" are inappropriate in R&D environments and can lead to a short term focus that doesn't truly support the organization's strategy (Metawie & Gilman, 2005; Neely, Gregory, & Platts, 1995). Significant work has been done in recent years to develop performance measurement systems which use systems perspectives which establish essential indicators that take multiple perspectives and dimensions into account, but there is still not a universally accepted framework for building an effective performance measurement system (Kennerley & Neely, 2002, Kressens-van Dronglen & Cook, 1997, Meyers & Hester, 2011). Different stakeholders will have differing perspectives which will drive the way they interpret "effectiveness." Using a "cookie cutter" approach to performance measurement, especially in an R&D environment, is inadequate because of the uniqueness of each system. Different systems mean different outputs, outcomes, stakeholders, and environments.

A performance measurement system should produce metrics that support the company's mission and are designed such that multiple perspectives are taken into account so that, when implemented at multiple hierarchical levels in an organization, they produce the intended outcomes (Kaplan & Norton, 2007; Metawie & Gilman, 2005; Neely et al., 2005). A well designed measurement system will define what different metrics will be used for, what benefits they provide, how much they cost to implement, how they balance both long and short-term objectives, how they integrate with a company's incentive structure, how they adequately consider customer satisfaction and measure-up against the competition (Neely et al., 2005). If properly implemented, a PMS will provide managers, at all levels in the organization, a clear definition of what actions are required to effectively implement the organization's strategy (Bremser & Barsky, 2004; Pearson & Kerssens-van Drongelen, 2000).

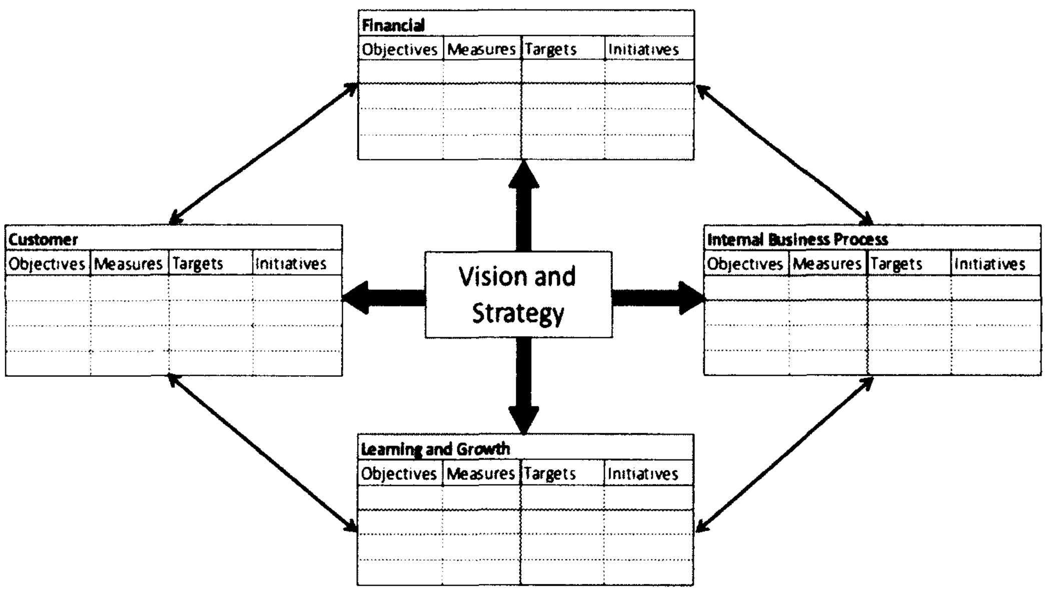
Several authors have developed performance measurement system frameworks. Two of the most recognized are the Balanced Scorecard (1992) and the Performance Prism (2002). The Balanced Scorecard, stressing causal linkages between multiple perspectives, is currently a widely accepted performance measurement tool (Northcutt & Taulapapa, 2012). The Performance Prism was developed to address perceived limitations in the Balanced Scorecard with respect to stakeholder management (Metawie & Gilman, 2005; Neely et al., 2002). The Performance Prism also approaches performance measurement from multiple perspectives. As each is a system, they provide direction as to how an organization should implement measures across different business units, their associated objectives, and the overarching objectives of the organization (Metawie & Gilman, 2005).

2.2.1 The Balanced Scorecard. Kaplan and Norton introduced the concept of the Balanced Scorecard in 1992. Rather than choosing between a single type of measurement, such as financial or operational, the Balanced Scorecard brings together both the financial and operational measures to create a more holistic picture of the state of the company. Kaplan and Norton's framework is centered on four questions:

- *How do customers see us? (customer perspective)*
- *How do we look to shareholders? (financial perspective)*
- *What must we excel at? (internal perspective)*
- *Can we continue to improve and create value? (innovation and learning perspective)*

The theory behind these four questions is that the company will be able to both look at multiple perspectives that affect the function of the company while also limiting the number of measures to those that are most critical. These framework features provide the template for organizations to implement a measurement system that concentrates on more than just simple financial indicators. Figure 3 shows how the four questions are translated to the performance measurement framework that supports the vision and strategy of the company.

Figure 3: Four perspectives for translating vision and strategy
(adapted from Kaplan & Norton, 2007, p. 4)



A strength of the framework is that it makes explicit the links between the different dimensions of business performance (Neely et al., 2000). The multiple perspectives of the framework have allowed the Balanced Scorecard to become extremely popular in modern day business management. Companies are able to use the

Balanced Scorecard to drive their processes and manage their strategies.

Kerssens-van Drongelen and Bilderbeck (1999) have adapted the Balanced Scorecard so that it can be implemented in an R&D environment. For example, they note that the financial perspective can be derived from other perspectives in the Balanced Scorecard: internal business, and innovation and learning. From these measures, higher-level management could make informed decisions concerning allocation of resources, career development, and reward structures (Kerssens-van Drongelen & Bilderbeck, 1999). The authors state that measurement system design is primarily determined by "the purpose of the measurement and the objectives formulated for the subject of the measurement" (Kerssens-van Drongelen & Bilderbeck, 1999, p. 38). They then identify five additional areas that affect measurement system design which they call "contingency factors." These are:

1. Organizational level
2. Type of R&D
3. Type of industry
4. Organizational size
5. Strategic control model

These factors are used to tailor the R&D measurement system including measures and procedures. Grouping of the performance measurements used in different companies shows that many of the R&D measures can be catagorized within the framework of the Balanced Scorecard, however, the measures most companies utilized were not balanced for the four perspectives at the individual or company level (Kerssens-van Drongelen & Bilderbeck, 1999). This would imply either a disconnect between practice and the theory or possibly a fundamental problem with the implementation of R&D measurement systems.

While the Balanced Scorecard provides a multi-perspective performance measurement system framework, there are still limitations that organizations will face as they attempt to implement it. Metawie & Gilman (2005) note that the Balanced Scorecard is designed primarily to provide an overview of performance and is not appropriate for implementation at the factory operations level. Critics cite the fact that it does not address the interests of multiple stakeholders or that measures are often inappropriately weighted based on barganing power of different stakeholders (Metawie & Gilman, 2005; Neely et al., 2000; Paranjape et al., 2006;). Additionally, while competitors may not be considered stakeholders, Neely, Gregory and Platts (2005) reveal an apparent flaw that an organization may face by not considering this group. They point out that if an organization were to develop a set of performance measures from the Balanced Scorecard, they would not be able to answer the fundamental question - "what are our competitors doing?" (p. 1244). These aspects can have a negative impact on the long-term success of the PMS.

Others argue that the Balanced Scorecard framework does not provide practical guidance on the way measures must be identified, populated into the framework, and used to manage performance (Neely et al., 2000). While identification of important measures may be seen as a problem for many managers, scaling the number of measures down to a sustainable amount that both provides an accurate snapshot of an organization and also doesn't overwhelm the system is a much more difficult task (Neely et al., 2005). Therefore, being able to assess the implemetation of the Balanced Scorecard is essential.

When its perspectives are blindly followed,"excessive, redundant or flawed measures that drive inappropriate behaviours" (Paranjape et al., 2006, p. 11) can occur.

2.2.2 The Performance Prism. The Performance Prism (Neely et al., 2002) was introduced as a measurement framework that would address measurement from a different perspective than previous PMSs. The authors contend that other performance measurement systems, such as the Balanced Scorecard, centered primarily on strategies. They argue that designing performance measures around strategy has led to organizations failing to consider fully what they are truly hoping to accomplish: satisfied stakeholders. The performance prism includes five facets based around stakeholder perspectives:

1. **Stakeholder Satisfaction-** Who are our stakeholders and what do they want and need?
2. **Strategies** - What strategies do we need to put in place to satisfy these sets of wants and needs?
3. **Processes** - What processes do we need to put in place to satisfy these sets of wants and needs?
4. **Capabilities** - What capabilities – bundles of people, practices, technology and infrastructure – do we need to put in place to allow us to operate our processes more effectively and efficiently?
5. **Stakeholer Contribution** - What do we want and need from our stakeholders? (adapted from Neely et al., 2002, p. 4)

The strategy itself is not the end game; it is the way in which the organization attempts to accomplish its goal of satisfying the stakeholders. Questioning the basis for an organization's strategy with respect to stakeholder perspectives prior to selecting measures is a strength of the Performance Prism (Tangen, 2005). The term "stakeholder" represents more than just shareholders. In addition to the investors, it includes customers, employees, suppliers, regulators, community, etc. (Metawie & Gilman, 2005). The authors of the Performance Prism believe that to be successful, a company must have a clear picture of who the relevant stakeholders are and what they want and by understanding and addressing the stakeholders' needs holistically a company can create an effective performance measurement model capable of supporting the long term success of the organization.

2.2.3 Other Performance Measurement Systems. Although not as popular as the Balanced Scorecard and Performance Prism, several other frameworks have been developed to guide the development of performance measures in organizations. The Performance Measurement Matrix (Keegan, Eiler, & Jones, 1989), like the Balanced Scorecard, links different dimensions of performance including financial and non-financial costs and internal and external focus. The Results and Determinants framework (Fitzgerald, Johnson, Brignall, Sivestro, & Voss, 1991) links results to determinants. The authors tie results to competitive performance and financial performance while tying determinants to quality of service, flexibility, resource utilization and innovation. By doing this, the framework highlights the determinants as leading indicators of future results (Neely et al., 2000). The Performance Pyramid (Lynch & Cross, 1991) is a hierarchical four-level pyramid which links strategic objectives top down while linking performance measures bottom up (Ojanen & Vuola, 2003). It also identifies linkages of both internal and external performance measures. Although each of these frameworks has their differences, they all provide guidance that their authors assert will lead to improved performance. With all the guidance that can be found in the literature, one is left to question: *Why do so many implementations fail?*

2.2.4 Why Performance Measurement System Implementations Fail. As previously noted, there are many unsuccessful implementations of the performance measurement systems, such as the Balanced Scorecard, in part because, when PMS design perspectives are blindly followed and allowed to constrain the PMS itself, they can lead to "excessive, redundant or flawed measures that drive inappropriate behaviours" (Paranjape et al., 2006, p. 11). The usefulness of the implementation of the PMS is therefore dependent on the person or team correctly understanding the intentions of the PMS framework and their skill at developing the right measures. Creating a useful PMS may require technical assistance which may not always be available (Wholey & Newcomer, 1997). Lack of proper skill, knowledge, or assistance can lead to a flawed performance measurement system implementation and although there has been significant work by practitioners to refine the way in which effective performance measurement systems can built, little work can be found on the effectiveness of PMS implementations (Bourne et al., 2002). This presents a significant issue.

Scholarly literature suggests that as many as 70% of PMS's fail as a result of their implementations (Neely & Bourne, 2000). Further, Wall and Counet (2009) conducted a survey with experts in the field. They found that these experts believe that an average of 56% of PMS implementations fail because of implementation problems. This general agreement between scholars and practitioners concerning the failure rate of PMS implementations leads to the question: *what makes a PMS implementation fail?*

It has been suggested that PMS implementation failures can generally be placed into three categories: context, process, and content (Bourne et al., 2002). The first category, context, is concerned with how an implementation will be effected in its environment. Earlier work by Neely and Bourne (2000) also detail three categories associated with PMS failures: political, infrastructural, and focus. While these categories are integral to PMS success and failure, evaluating these categories leads one to realize that they are all contextual issues and can therefore be embedded within this category. The second failure categories identified is process. Process concerns the robustness of the PMS with regards to how well an implementation meets the intentions of the PMS framework design. Content refers to the measurements themselves and how well they meet the intentions and needs of the system. Table 5 details specific failure causes associated with each category.

Table 5: Main reasons for performance measurement implementation failures.
(adapted from: Bourne et al., 2002)

PMS Failures		
Context	**Process**	**Content**
The need for a highly developed information system	Vision and strategy were not actionable as there were difficulties in evaluating the relative importance of measures and the problems of identifying true ``drivers''	Strategy was not linked to department, team and individual goals
Time and expense required	Strategy was not linked to resource allocation	Large number of measures diluted the overall impact
Lack of leadership and resistance to change	Goals were negotiated rather than based on stakeholder requirements	Metrics were too poorly defined
	State of the art improvement methods were not used	The need to quantify results in areas that are more qualitative in nature
	Striving for perfection undermined success	

These failure causes align with Wall and Counet (2009), who compiled a list of problems gathered from practitioner feedback and relevant literature to categorize PMS implementation issues. They went on to complete a factor analysis on the results which produced the following PMS implementation problems:

1. Insufficient commitment from middle management and staff for PMS implementation
2. There is resistance from organizational members towards the new PMS
3. Management puts low priority on the PMS implementation
4. The system lacks cause and effect relations or is overly-complex due to too many causal relations
5. The current information-and-communication technology system does not support the PMS adequately
6. There are insufficient resources and capacity available for the implementation
7. There is a lack of knowledge and skills in regard to the PMS
8. The PMS is not used for the daily management of the organization

This problem list also aligns well with the context category identified earlier. These findings point to a fundamental issue associated with performance measurement system frameworks: while PMS frameworks can provide a solid base for both process and content, the context in which the PMS resides must be properly understood and accounted for during implementation, as well as during the PMS's life cycle, to provide a foundation for success.

Over-reliance on quantitative measurement can also present a problem in a PMS implementation. Several drawbacks, many associated with the R&D environment, exist that point to a need for balancing qualitative measures in many situations. This is an issue associated with the content PMS failure mode. Organizations that rely too heavily on quantitative measures may be missing a part of the bigger picture that can be more readily seen through a qualitative lens. Brown and Gobeli (1992) list some of the pitfalls associated with quantitative measurement including:

- They don't work well in professional groups, such as in R&D organizations, where much of the work is characterized by uncertainty and variability, and the outputs are relatively intangibles.
- They don't work well where projects and products are customized, as is the case in many high-tech, contract research situations.
- They don't allow for important subjective perceptions of much professional work, as when sales of a complex, technical product arc heavily dependent on customer perceptions of the ease and availability of product maintenance and repair.
- They don't adequately measure the long-term outcome of an emerging technology or a new product's development, i.e., the strategic importance of such developments to broader corporate goals.
- They generally leave out social factors, and thus provide little help to managers in evaluating leadership styles, communication patterns, etc.

Neely and Bourne (2000) identify a feedback problem associated with many PMSs: failure of the organization to actually use measurement information. If an organization has not implemented a system that uses the performance measurement data to improve itself, then how can the PMS truly be valuable? The changes that drive improvement must come from the analysis of the performance measures and decisions must be made to affect improvement over time.

These cited issues provide the foundation for understanding why PMS implementations often fail. If organizations use quantitative measures where a qualitative understanding is required or if a measurement system is not built from the organization's mission, or if the environment that the PMS is being developed for is not well understood then the PMS implementation has a higher chance for failure. However, it cannot be assumed that organizations that implement a PMS simply ignore these issues. The high failure rate of implementations supports the belief that many of these issues are not easily identified during the implementation phase nor are the issues corrected after implementation. An assessment framework that allows a company to consider these issues and make corrections to their PMS could provide a means to reduce the failure rate of PMS implementations.

2.3 ASSESSMENT OF PERFORMANCE MEASUREMENT SYSTEM IMPLEMENTATIONS

While there is significant literature pertaining to performance measurement systems, significantly less information appears in the literature with respect to assessment of performance measurement system implementations. The optimal PMS for organizations will vary from case to case (Tangen, 2005) and in different settings (Neely & Bourne, 2000), which means a pre-determined set of metrics cannot be used for different implementations. There is a need for a structured methodology available for practitioners to assess their PMS (Medori & Steeple, 2000). People implementing a PMS need to be able to answer the question "how have we done?" To address this question, the literature provides some examples to draw from, beginning with the performance questionnaire.

2.3.1 Performance measurement questionnaire. Dixon, Nanni, and Volmann (1990) suggest that companies go through three phases of change as they move away from traditional cost accounting techniques towards more holistic measurement methods. These three phases consist of:

1. *Tinkering with the cost accounting system*
2. *Cutting the Gordian Knot (separating performance measures from traditional cost accounting)*
3. *Embracing change in strategies, actions, and measures.*

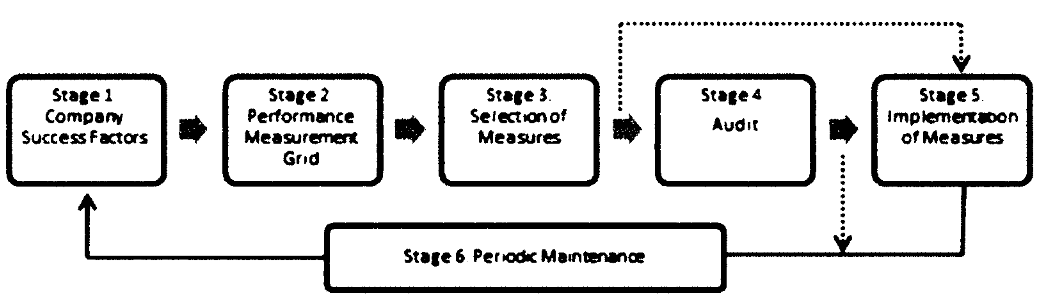
(1990, p. 21)

The authors present a performance measurement questionnaire as a means to "cut the Gordian knot" by helping companies understand the inadequacies in their PMS and make necessary improvements. Although the questionnaire was developed in 1990, it addresses some of the foundational aspects recognized in many of the current PMS frameworks such as measurements consistent with strategy, actionable measures, consensus building, and continuous improvement. In the questionnaire, the respondents are asked to rate different performance factors using two different scales. The first scale rates the degree to which the respondent believes a performance factor is important to the long term health of the organization. The second scale rates the degree to which the respondent believes the organization places emphasis on the associated measure. Results from the scale can then be used to both align the organizations performance measures with strategy, determine the extent to which the performance measures support the strategies, and identify what the authors refer to as "gaps" (areas where new measures are required) and "false alarms" (areas where existing measures are not useful) (Dixon et al., 1990, p. 77).

The questionnaire provides a basis for PMS assessment (Cocca & Alberti, 2010; Medori & Steeple, 2000; Tangen, 2005). It is built for managers to be able to easily administer and provide understandable results. However, it is built from the perspective of commercial industry PMS assessment and cannot be readily translated for use in an R&D context. Also, the questionnaire does not address classification of systems or stakeholders (Tangen, 2005).

2.3.2 Performance measurement grid and checklist. Medori and Steeple (2000) build on Dixon, Nanni, and Volmann's (1990) performance measurement questionnaire and present a six stage process that is used to identify unused measures and gaps. Their design requirements for the PMS audit framework were compiled using information from four manufacturing organizations. The performance measurement grid and checklist is designed to determine if an organization's measurement system is tied to strategy, up to date, and measuring what is intended. There stages of the framework are shown in Figure 4.

Figure 4: Performance measurement audit framework
(adapted from Medori & Steeple, 2000, p. 523)



The framework provides an audit function which integrates learning into the PMS implementation. Information gained from the audit function can be fed back into the system to drive iterative improvement.

2.3.3 PMS System Class Ranking System. Tangen (2005) also builds on Dixon et al. (1990) to develop an assessment framework to rate a PMS. He suggests using three system classes:

1. **First class – Fully Integrated**
   - The most advanced classification. Identifies causal relationships throughout the organization, considers the needs of relevant stakeholders, has integrated information sharing of reporting system data and is updated continuously.
2. **Second class – Balanced**
   - Has a multidimensional view of performance and supports learning and innovation.
3. **Third Class – Mostly Financial**
   - The PMS is based on traditional accounting based performance measures, and has a short term focus.

To assess and improve the PMS, the author provides three steps – requirement evaluation, system class determination, and revision of the PMS. Requirement evaluation consists of assessing the degree to which the PMS meets the requirements of the system. System class determination identifies the class of the system based on the assessment. The revision of the PMS both identifies the requirements that need to be improved with in a system classification and identifies the requirements needed to be implemented to move to a higher system classification (Tangen, 2005).

2.3.4 Integrated performance measurement system (IPMS). Bititci, Turner, and Begemann (2000) propose a framework that can be utilized in the development of dynamic performance measurement systems. In their model, the PMS is dynamic in that it is sensitive to internal and external changes in the environment and organization, can review and reprioritize internal objectives based on these changes, deploy changes, and monitor gains achieved through the improved changes (Bititci et al., 2000). These characteristics offer the ability of the system to offer a dynamic, closed loop control, mechanism for the PMS. To accomplish this, the authors suggest that two parts are necessary to accomplish these requirements: a framework and an IT platform. Together, these pieces create the integrated performance measurement system (IPMS) reference model. This model aims to fulfill a number of significant requirements. These are presented under two elements as follows:

- **Framework**
    - External control system
    - Review mechanism
    - Deployment system
    - Causal relationships
    - Quantify criticality
    - Internal control system
    - Gains maintenance
    - Alarm signal

- **IT platform**
    - Provide an executive information systems
    - Accommodate the elements of framework
    - Is integrated with the existing business environment
    - Can handle simple rules like raising alarm signals.

Bititci, Turner, and Begemann (2000) assert that closed loop control is well understood with respect to performance measurement systems although is not often used in this dynamic fashion in practice. One limitation was identified to be that development of the review mechanism in complex scenarios required further work. However, they propose that the IPMS model offers practitioners the ability to develop effective, dynamic performance measurement systems with the aid of currently available technology excepting this limitation (Bititci et al., 2000).

2.3.5 Improvement System Assessment Tool. Van Aken, Letens, Coleman, Farris, and Van Goubergen (2005) discuss an improvement system assessment tool that can be used to rate the maturity and effectiveness of a performance measurement systems. It is built to evaluate several areas of a multidimensional PMS such as alignment, maturity, and performance levels. This framework was tested in a public sector setting versus many of the other PMS assessment tools which were built with commercial interests in mind. Four scoring dimensions are proposed: approach, deployment, study, and refinement. This tool is useful at the enterprise level to assess PMSs in an integrated system context. However, the framework does not explicitly address performance measurement within the R&D context; for example, how to determine if a measure is useful and necessary in support of the R&D mission.

2.3.6 Other PMS assessment frameworks. Several other models exist to assist with assessment of performance measurement systems such as the Four Stage PMS Maturity Model (Wettstein & Kueng, 2002), which rates the maturity of multiple assessment areas, the Small and Medium Size Enterprise PMS Assessment (Cocca & Alberti, 2010), which develops a maturity grid for PMS assessment based on literature derived best practices, and the Structured Framework for the Review of Business Performance (Najmi & Rigas, 2005), which reviews business and PMS performance based on the PMS design process characteristics in Neely et, al. (2000). However, at this time, the author of this dissertation can find no work explicitly dedicated to an assessment framework for PMS implementations in the R&D setting utilizing a systems-based approach. The following section will therefore present a discussion on systems theory and how its approach and principles add to the significance of this dissertation's proposed PMS assessment framework.

2.4 SYSTEMS THEORY

Performance measurement systems are built to provide guidance for complex systems that involve managers, processes, customers, suppliers, shareholders, stakeholders, policies, politics, and the environment. This is to say that they operate in a real world system. Systems theory offers a means by which to address complex organizational issues (Ackoff, 1999) such as those found in PMS implementations. Reductionist "divide and conquer" techniques are often employed by engineers and scientists to reduce problems to manageable parts, solve the individual parts, and then reassemble the solutions into an overall solution to the larger problem. However, this approach fails to recognize the true nature of complex systems. Complex systems can't adequately be understood by looking at the individual pieces of the system. The behavior of the total entity is more than can be understood by understanding the behavior of its individual elements (Clemson, 1984; Mitroff, 1998). A *systems approach* deals with complex systems as entities in their totality rather than as the sum of their parts (Scott L. , 2005). The systems approach demands a mode of systems thinking. It is an epistemology based on understanding the characteristics of human activity systems, holistically, with regards to emergence, hierarchy, communication and control (Checkland, 1993).

Flaws can be present in PMS implementations such as a narrow set of metrics, short term goals, or backwards looking accounting based measures (Kaplan & Norton, 1992; Meyers & Hester, 2011; Neely & Bourne, 2000). Problems areas will inevitably emerge from flaws such as these and a systems approach can inform the way a system's hierarchy, communication and control mechanisms can affect, for better or for worse, these emergent issues. PMS implementation problems can and should be expected in scientific settings, such as R&D organizations. This is because engineers and scientists, while often brilliant, are generally trained in a single discipline and unskilled in truly systemic thinking. Scientific and engineering processes use the process of analysis to obtain repeatable results through minimizing the number of variables. This method alone does not holistically evaluate problems in a way that captures a problems entire complexity. Often the scientific approach is not fundamentally concerned with the human aspects affecting a problem, interactions between problem elements, or changes that happen as a result of emergent conditions. However, a systems approach does consider issues such as these, and it is vitally important if one desires to create a useful model of any organizational system and system thinking provides "a kind of thinking that is better suited for the biological and behavioral realms" (Skyttner & Rose, 1997, p. 34).

A systems approach to PMS implementation assessment must be able to provide a lens through which the practitioners can view their implementation with regards to structured systemic thinking. A systems-based framework must identify problem areas in a PMS implementation that often happen when managers are looking to oversimplify or when they believe that they can disregard existing social aspects. The systems approach avoids reductionism and looks at problems within the context of the larger human activity systems (Checkland, 1993) such as the system performance measures are implemented within.

2.4.1 Systems concept. When looking at the world in its entirety it is impossible to deal holistically with all the complexity it offers. Instead, science has provided methods of analysis for dealing with the complexity we see by teaching us to reduce and dividing complex problems into manageable pieces that we can examine. Many of these divisions are formalized as subjects or disciplines with which we have become familiar such as physics, biology, and psychology; however, it is important to remember that these are man-made divisions imposed on nature so that we can try to understand the world around us (Checkland, 1993).

The reductionist approach is often useful in studying simple problems. However divisions in complex problems, such as those in social phenomena, are far less clear. Checkland (1993) explains the difference using an example. Heat transfer can be studied in a laboratory so that properties can be understood separate from other physical phenomena such as light, sound, gravity, etc. The physical properties learned in the experiment continue to hold true even when they are reintroduced into an environment where the properties of these other phenomena are changed. This may lead one to believe that the process can be applied to more complicated systems to help develop an understanding of it. However, things get much more difficult when attempting to predict system behavior such as the behavior of humans in social settings in the phenomena of voting. Deciding what to include and exclude in an experiment to understand the dynamics of voting thus becomes much harder to identify (Checkland, 1993). To understand the complex social structures, or whole systems, including those that involve human interactions such as occur in organizations, one must consider the interactions and relations of the constituent systems that result in emergent behavior of the whole system. However, patterns of behavior emerge from operation of the system, and these emergent properties cannot be explicitly predicted in advance (Aristole, 2002). Checkland (1993) defines a system as:

> *The model of a whole entity; when applied to human activity, the model is characterized fundamentally in terms of hierarchical structure, emergent properties, communication, and control. An observer may choose to relate this model to real world activity. When applied to natural or man-made entities, the crucial characteristic is the emergent properties of the whole.* (pp. 317-318)

A system can be thought of as a group of elements connected by relationships that influences the emergent behavior of the whole. This leads to the need to define what a system is and how to identify it. To help identify a system, Ackoff (1999) prescribes a set of conditions:

A system is a set of two or more elements that satisfies the following three conditions.

1. *The behavior of each element has an effect on the behavior of the whole.*
2. *The behavior of the elements and their effects on the whole are interdependent.*
3. *However subgroups of the elements are formed, each has an effect on the behavior of the whole are none has an independent effect on it.* (p. 16)

Systems cannot, therefore, be divided up using a reductionist approach and analyzed in a way that will produce an accurate understanding of the behavior of the whole. Ackoff (1999) also notes that "when a system is taken apart it loses its essential properties" (p. 16). Therefore, it becomes clear that the process of analysis, championed by Descartes, falls short of what is required to frame an understanding of systems (Checkland, 1993; Ackoff, 1999). Instead, a construct for dealing with complex systems is needed. The following section discusses a construct that can be used to create a better understanding of the behavior of systems.

2.4.2 The systems theory construct. Systems theory creates a methodological framework suitable for systemic thinking about organizational issues. Systems theory guides the approach to issues that must take system relationships, interactions, and integration into consideration (Ackoff, 1999). When utilizing a systems methodology, a problem must be thought of in holistic terms so that the problem definition and the accompanying recommendations and solutions are designed to be contextually adaptable. As such, there are associated strengths and weaknesses associated with the approach as discussed by Hester, Baggett, Shauger, and Haynes (2010):

The strengths of a systems methodology include systemic structure of thinking, design, and execution; explicit logic and rationale in approach;

implicit logic of systems philosophy; accepted, understood, and proven approaches to the design and analysis of system problems or situations; and language and philosophy of holistic inquiry. Conversely, the limitations of a systems methodology include additional layers of complexity, including consideration of compatibility with context, infrastructure, values, and worldview; determination and alignment of approach, decision, action, and interpretation, outputs and outcomes, and compatibility; and systems expertise and maturity.(p. 575)

The systems approach is appropriate for creating a functional understanding of the implementation of PMS's in organizational settings. Therefore, it is compulsory to provide a definition of what the author of this dissertation means by the term systems theory when discussing the subject. Adams, Hester, Bradley, Meyers, and Keating (2014) developed a formalized definition and construct of systems theory built from the unification of specific propositions and principles, derived from over 40 individual fields of science, into an axiom set. The construct defines a way for real world systems to be evaluated so that one can seek to gain a more complete understanding of them. The authors propose seven axioms that together form the basis for systems theory. These are:

1. <u>The Centrality Axiom</u> states that *central to all systems are two pairs of propositions; emergence and hierarchy, and communication and control.*
2. <u>The Contextual Axiom</u> states that *system meaning is informed by the circumstances and factors that surround the system.* The contextual axiom's principles are those which give meaning to the system by providing

guidance that enable an investigator to understand the set of external circumstances or factors that enable or constrain a particular system.

3. The Goal Axiom states that *systems achieve specific goals through purposeful behavior using pathways and means*. The goal axiom's principles address the pathways and means for implementing systems that are capable of achieving a specific purpose.
4. The Operational Axiom states that *systems must be addressed in situ, where the system is exhibiting purposeful behavior*. The operational principles provide guidance to those that must address the system in situ, where the system is functioning to produce behavior and performance.
5. The Viability Axiom states that *key parameters in a system must be controlled to ensure continued existence*. The viability principles address how to design a system so that changes in the operational environment may be detected and affected to ensure continued existence.
6. The Design Axiom states that *system design is a purposeful imbalance of resources and relationships*. The design principles provide guidance on how a system is planned, instantiated, and evolved in a purposive manner.
7. The Information Axiom states that *systems create, possess, transfer, and modify information*. The information principles provide understanding of how information affects systems.

(Adams et al., 2014, pp. 5-6)

These axioms provide the "lens" through which one can look at a system, including organizational systems, and their associated issues and behaviors as they occur in the real world. Any systems methodology should be informed by this systems theory as described in these axioms. It can be used to build a methodology that can deal with organizational elements such as products, processes, resource allocation, learning, vision, and social issues the investment of organizational leadership, involvement of key managers, supervisors, and technicians, as well as participation of relevant stakeholders (Wholey & Newcomer, 1997), which are all critical for the establishment of an effective performance measurement system.

The axiom set provides a foundation for systems theory and systems thinking. As stated, they are built from the unification of specific propositions and principles. Therefore, system principles, and their implications for performance measurement, is discussed in the following section.

2.4.3 System principles. Systems principles are used to provide a set of fundamental definitions that establish a systematic way to guide systemic thinking. This allows the researcher to address the issues surrounding real-world system complexity. A summary of these principles is presented in Table 6. These principles form the set of propositions that mutually support the seven guiding axioms of systems theory detailed earlier in this section. These systems principles are used to help us understand the system from a holistic perspective and different worldviews. Together, they paint a picture of the real way a system operates. Understanding the human aspects associated with complex systems in all their richness is important to the understanding of the effectiveness, or lack thereof, of performance measurement system implementation. The literature agrees, stating that PMS implementations cannot be successfully accomplished without taking human behavior into account (Neely & Bourne, 2000; Waal & Counet, 2009).

Table 6: Systems principles

(from Adams et al., 2014)

Axiom	Proposition and Primary Proponent	Brief Description of the Systems Proposition
Centrality	Communication (Shannon , 1948)	In communication, the amount of information is defined, in the simplest cases, to be measured by the logarithm of the number of available choices. Because most choices are binary, the unit of information is the bit, or binary digit.
	Control (Checkland, 1993)	The process by means of which a whole entity retains its identity and/or performance under changing circumstances.
	Emergence (Aristole, 2002)	Whole entities exhibit properties which are meaningful only when attributed to the whole, not its parts – e.g. the smell of ammonia. Every model of systems exhibits properties as a whole entity which derives from it component activities and their structure, but cannot be reduced to them.
	Hierarchy (Pattee, 1973)	Entities meaningfully treated a wholes are built up of smaller entities which are themselves wholes . . . and so on. In a hierarchy, emergent properties denote the levels.
Contextual	Complementarity (Bohr, 1928)	Two different perspectives or models about a system will reveal truths regarding the system that are neither entirely independent nor entirely compatible.
	Darkness (Cillers, 1998)	Each element in the system is ignorant of the behavior of the system as a whole, it responds only to information that is available to it locally. This point is vitally important. If each element „knew" what was happening to the system as a whole, all of the complexity would have to be present in that element.
	Holism (Smuts, 1926)	The whole is not something additional to the parts: it is the parts in a definite structural arrangement and with mutual activities that constitute the whole. The structure and the activities differ in character according to the stage of development of the whole; but the whole is just this specific structure of parts with their appropriate activities and functions.

(Table 6 Continued)

Design	Minimum Critical Specification (Cherns, 1976, 1987)	This principle has two aspects, negative and positive. The negative simply states that no more should be specified than is absolutely essential; the positive requires that we identify what is essential.
	Pareto(1897)	Eighty percent of the objectives or outcomes are achieved with twenty percent of the means.
	Requisite Parsimony (Millar, 1956)	Human short-term memory is incapable of recalling more than seven plus or minus two items.
	Requisite Saliency (Boulding, 1966)	The factors that will be considered in a system design are seldom of equal importance. Instead, there is an underlying logic awaiting discovery in each system design that will reveal the saliency of these factors.
Goal	Equifinality (Bertalanffy, 1950)	If a steady state is reached in an open system, it is independent of the initial conditions, and determined only by the system parameters, i.e. rates of reaction and transport.
	Multifinality (Buckley, 1967)	Radically different end states are possible from the same initial conditions.
	Purposive Behavior (Roseenblueth, Wiener, & Bigelow, 1943)	Purposeful behavior is meant to denote that the act or behavior may be interpreted as directed to the attainment of a goal-i.e., to a final condition in which the behaving object reaches a definite correlation in time or in space with respect to another object or event.
	Satisficing (Simon, 1974)	The decision making process whereby one chooses an option that is, while perhaps not the best, good enough.
	Viability (Beer, 1979)	A function of balance must be maintained along two dimensions: (1) autonomy of subsystem versus integration and (2) stability versus adaptation.
Information	Redundancy of Potential Command (McCulloch, 1959)	Effective action is achieved by an adequate concatenation of information. In other words, power resides where information resides.
	Information Redundancy (Shannon & Weaver, 1949)	The number of bits used to transmit a message minus the number of bits of actual information in the message.

(Table 6 Continued)

Operational	Dynamic equilibrium (d'Alembert, 1743)	For a system to be in a state of equilibrium, all subsystems must be in equilibrium. All subsystems being in a state of equilibrium, the system must be in equilibrium.
	Homeorhesis (Waddington, 1957)	The concept encompassing dynamical systems which return to a trajectory, as opposed to systems which return to a particular state, which is termed homeostasis.
	Homeostasis (Cannon, 1929)	The property of an open system to regulate its internal environment so as to maintain a stable condition, by means of multiple dynamic equilibrium adjustments controlled by interrelated regulation mechanisms.
	Redundancy (Pahl, Beitz, & Grote, 2011)	Means of increasing both the safety and reliability of systems by providing superfluous or excess resources.
	Relaxation Time (Holling, 1996)	Stability near an equilibrium state, where resistance to disturbance and speed of return to the equilibrium are used to measure the property. The system's equilibrium state is shorter than the mean time between disturbances.
	Self-organization (Ashby, 1947)	The spontaneous emergence of order out of the local interactions between initially independent components.
	Suboptimization (Hitch, 1953)	If each subsystem, regarded separately, is made to operate with maximum efficiency, the system as a whole will not operate with utmost efficiency.
Viability	Circular causality (Foerster, Mead, & Teuber, 1953)	Any effect becomes a causative factor for future effects, influencing them in a manner particularly subtle, variable, flexible, and of an endless number of possibilities.
	Feedback (Wiener, 1948)	All purposeful behavior may be considered to require negative feed-back. If a goal is to be attained, some signals from the goal are necessary at some time to direct the behavior.
	Recursion (Beer, 1979)	The fundamental laws governing the processes at one level are also present at the next higher level.
	Requisite Hierarchy (Aulin-Ahmavaara, 1979)	The weaker in average are the regulatory abilities and the larger the uncertainties of available regulators, the more hierarchy is needed in the organization of regulation and control to attain the same result, if possible at all
	Requisite Variety (Ashby, 1956)	Control can be obtained only if the variety of the controller is at least as great as the variety of the situation to be controlled.

The author of this dissertation believes that a framework for R&D PMS implementation assessment should utilize the axioms and principles noted above to guide the framework's design. This systems-based approach allows for a holistic solution that considers multiple aspects, as detailed in the seven axioms, that are associated with PMS implementations within complex systems; in this case, R&D organizations. Based on the literature to date, the detailed systems-based approach defined in this section has not been utilized in the construction of an R&D PMS implementation assessment framework. Therefore, the final section of this chapter discusses the way in which the literature can be synthesized to fill this gap that currently exists.

2.5 SECTION SUMMARY AND IDENTIFICATION OF GAP

The literature streams discussed in this chapter include performance measurement systems, performance measurement in R&D, performance measurement system assessment, and systems theory. Performance measurement system frameworks such as the Balanced Scorecard (1992) and Performance Prism (2002) are built to guide organizations in designing measurement systems. They point out areas where measures may be useful but often stop short of providing the guidance that is necessary to identify, establish and use the measures to reach the organizations desired goals (Neely et al., 2000). Aspects of R&D have made performance measurement in the field extremely difficult to measure and control (Kerssens-van Dronglen & Cook, 1997; Ojanen & Vuola, 2003) and have led to a preclusion of any widely accepted set of R&D performance measures (Ojanen & Vuola, 2003; Szakonyi, 1994b). While some literature exists on PMS assessment, the area of study seems to be in its embryonic stage and the author of this dissertation found no studies dedicated expressly to R&D PMS implementation assessment. Finally, while many PMS frameworks give consideration to systems theory perspectives, the PMS assessment frameworks are not expressly built from a structured systems-based methodological approach. Synthesis of the areas reviewed in this chapter (Figure 5) provided the basis to fill the knowledge gap that currently exists.

The literature provides a significant data source to guide the development of performance metrics and the design of performance measurement systems. However, much of the literature only offers theoretical perspective on PMS design. This leads to a gap between the PMS framework theory and PMS implementation, especially in the case of R&D organizations. Organizations often attempt to "repackage" their exiting, and sometimes inappropriate, performance metrics into a PMS framework, such as the Balanced Scorecard, or fail to recognize the challenges associated with PMS implementation (Neely & Bourne, 2000). A tool is needed for them to be able to assess their PMS effectiveness.

PMS frameworks provide a theoretical foundation for designing an organization's performance measurement system. However, when an organization tries to apply the framework empirically, they may interpret the "rules" of the framework differently than the way it was intended to be applied. This provides ambiguity in the implementation process of performance measurement systems at the enterprise level.

Figure 5: Synthesizing threads to fill the R&D PMS implementation assessment gap

Performance Measurement in R&D

Behn	2003
Bremser, Barsky	2004
Brown, Gobeli	1992
Chiesa, Frattini, Lazzarotti, Manzini	2007
Hester, Meyers	2011
Hester, Meyers	2012
Keating, Hester, Kady, Calida	2009
Kerssens-van Dronglen, Bilderbeek	1999
Kerssens-van Dronglen, Cook	1997
Kumpe, Bolwijn	1994
Lim, Park	2006
Meyers, Hester	2011
Ojanen, Vuola	2003
Pearson, Kerssens-Van Drongelen	2000
Poh	2001
Smith, Clark	2006
Smith, Clark	2004
Sproles	2000
Sproles	2001
Sproles	2002
Stevens	1979
Szakonyi	1994
Szakonyi	1994
Wholey, Newcomer	1997

Performance Measurement Systems

Bitici, Turner, Begemann	2000
Bourne, Neely, Mills, Platts	2003
Bourne, Neely, Platts, Mills	2002
Bremser, Barsky	2004
Ho, McKay	2002
Kaplan	2009
Kaplan, Norton	1992
Kaplan, Norton	2005
Kennerley, Neely	2002
Kerssens-van Dronglen, Cook	1997
Kleingeld, Tuijl, Algera	2004
Lynch, Cross	1991
Metawie, Gilmann	2005
Neely, Bourne	2000
Neely, Adams, Kennerley	2002
Neely, Gregory, Platts	1995
Neely, Mills, Platts, Richards, Gregory, Bourne, Kennerley	2000
Northcutt, Taulapapa	2012
Paranjape, Rossiter, Pantano	2006

PMS Assessment

Cocca, Alberti	2010
Dixon, Nanni, Volmann	1990
Harty	1999
Keegan, Eiler, Jones	1989
Medori, Steeple	2000
Najmi, Rigas	2005
Neely, Bourne	2000
Paparone, Crupi	2006
Tangen	2005
Van Aken, Letens, Coleman, Farris, Van Goubergen	2005
Wall, Counet	2009
Wettstein, Kueng	2002

Systems Theory

Ackoff	1999
Adams, Hester, Bradley, Meyers, Keating	2014
Beckerman	2000
Boland, Fowler	2000
Bozeman, Bretschnieder	1994
Checkland	1993
Clemson	1984
Hester, Meyers	2012
Hester, Baggett, Shauger, Haynes	2010
Keating	2000
Keating, Pyne	2001
Keating, Hester, Kady, Calida	2009
Meyers, Hester	2011
Mitroff	1998
Skyttner	1996

A Systems-Based Framework for the Assessment of Performance Measurement System Implementations in R&D Organizations

It has been noted that literature suggests that as many as 70% of PMS fail as a result of their implementations (Neely & Bourne, 2000, p. 3). A recent poll of experts suggests that even with the work done over the past decade with respect to establishing performance measures, 56% of PMS initiatives still fail (Waal & Counet, 2009). It seems obvious that many organizations would find it imperative to determine the effectiveness of their implementation early on in its deployment considering the investment that goes into establishing a PMS.

The author of this dissertation can find no work to this date detailing the assessment of performance measurement system design for R&D enterprise using a systems-based approach. Therefore, based on the existing literature, the lack of this assessment framework provides a significant gap that has been addressed through this research. An assessment framework designed to evaluate the effectiveness of a performance measurement system will provide a valuable instrument for organizations attempting to evaluate the effectiveness of their PMS implementation. The contribution of this dissertation is that it meets this need by providing this systems-based performance measurement system implementation assessment framework for R&D organizations for use at the enterprise level. The following section will discuss the methodology that was used to guide the development of the framework.

CHAPTER 3

RESEARCH METHODOLOGY

The purpose of this dissertation is to develop a systems-based framework for assessment of R&D performance measurement system implementations. The area of R&D research is populated with scientists and engineers who each have deep rooted beliefs in numeric and statistical methods to solve problem situations. Similarly, performance measurement systems produce results that can be analyzed using numerical methods such as number of patents received or number of reportable injuries. Still, the literature has shown that effectiveness of performance measurement systems is more than an empirical problem based on quantification of measurement efficiency. It is instead the ability of a system to identify relevant and balanced measurement areas, chose appropriate measures, and support the infrastructure to allow information to be stored, processed, communicated, and acted upon (Behn, 2003; Chiesa, Frattini, Lazzarotti, & Manzini, 2007; Kaplan & Norton, 1992; Neely et al., 2000). These concepts are both rational and empirical in nature, being best understood through analysis of data gained through observation and immersion in the area of study.

A grounded theory methodology was selected to both meet the requirements of the research questions as well as the nature of the system's complexity. The qualitative approach is appropriate for systems-based studies in that it is used to look at phenomena in their natural setting, to develop conclusions based on "all their complexity" (Leedy & Ormrod, 2010, p. 135) and to determine "the effectiveness of particular policies, practices, or innovations"(Leedy & Ormrod, 2010, p. 137). Gaining insight from both practitioners and literature concerning R&D performance measurement provided a broadened base to add confidence in the validity and a foundation to support the inductive generalization of the framework. The real world context in which PMSs are implemented and the complexity associated with evaluating enterprise organizations warrants the rigor associated with the qualitative methodology. Therefore, the author of this dissertation has chosen a grounded theory methodology as it is consistent with systems-based framework development, validation, and generalization developed in this dissertation.

This chapter describes the research methods including validity and reliability, research design, and data collection and analysis utilized in the following chapters to answer the research question as introduced in Chapter 1. They are reiterated as follows:

1. What operational characteristics are necessary for an effective R&D performance measurement system at the enterprise level?
2. What systems theory concepts apply to the assessment of performance measurement systems in an R&D environment?
3. How can R&D performance measurement system implementations be assessed from a systems perspective?

3.1 RESEARCH VALIDITY AND RELIABIILITY

Validity and reliability must be addressed in the research process and both have their place in both quantitative and qualitative research traditions. These terms are often used in the logical positivist traditions and are associated with quantitative research to show that data is legitimate by means of measurement accuracy, precision, repeatability, and significance (Pyett, 2003). In qualitative research, validity and reliability are also used as a means to establish the legitimacy of data. Many reserachers have adopted terms such as trustworthyness, quality, and rigor to address the concept of validity in qualitative research (Golafshani, 2003). However, the goal remains the same. Qualitative research seeks to use reliability and validity to create an accurate representation of a complex system or social phenomenon (Pyett, 2003). A discussion of validity and reliability thus follows.

3.1.1 Validity. Validity and reliability must be addressed in the research process and both have their place in both quantitative and qualitative research traditions. These terms are often used in the positivist traditions and are associated with quantitative research to show that data is legitimate by means of measurement accuracy, precision, repeatability, and significance (Pyett, 2003). Quantitative research focuses quantities by measuring a number of variables then uses the results from the research to make deductive predictions (Creswell, 2009; Leedy & Ormrod, 2010). In qualitative research, validity and reliability are also used as a means to establish the legitimacy of data although a different terminology is often utilized. For example, researchers that adopt the naturalist position have adopted terms such as trustworthyness, quality, and rigor to address the concept of validity in qualitative research. (Golafshani, 2003; Lincoln & Guba, 1985; Morse, Barrett, Mayan, & Olson, 2002). Using these concepts, qualitative researchers seek to create an accurate representation of a complex system or social phenomenon (Pyett, 2003). Hoepfl (1997) describes the different philosophies by stating: "where quantitative researchers seek causal determination, prediction, and generalization of findings, qualitative researchers seek instead illumination, understanding, and extrapolation to similar situations" (p. 48).

Despite their epistemological difference, there are basic similarities between the quantitative views of the positivists and qualitative views of the naturalist concerning validity and reliability. Indeed, the naturalist terminology parallels that of the positivists (Table 7). However, each methodological viewpoint is shaped by an associated ontology and epistemology. Positivists believe in a single reality that is "real" for everyone while naturalists believe that "realities are multiple, constructed, and holistic" (Lincoln & Guba, 1985, p. 37). Although the post-positivist viewpoints soften the positivist stance, these differences in viewpoints continue to shape the way different researchers describe validity and reliability. Table 7 describes the differences between the two paradigms with respect to what each paradigm considers to be defendable validity and reliability in research methodology and design.

Lincoln and Guba (1985) describe several techniques to address internal validity such as triangulation and member checks that can be utilized to provide credibility when interpreting qualitative research. Triangulation supports both internal and external validity and uses multiple sources of data in the hopes they provide a singular conclusion about data (Leedy & Ormrod, 2010) and member checks give the persons from which data was collected a chance to review the conclusions drawn by the researcher (Lincoln & Guba, 1985).

Table 7: Contrasting positivist and naturalist views (adapted from Lincoln & Guba, 1985)

Positivist (Quantitative)		Naturalist (Qualitative)	
Internal Validity	Extent to which an outcome (dependent) variable can be attributed to a controlled variation in an independent variable	Truth Value	Credible re-construction of (multiple) realities
External Validity	The approximate validity with which we infer that the presumed causal relationship can be generalized to and across alternate measures of the cause and effect and across different types of persons, settings, and times.	Applicability	Extent to which the findings have applicability in other contexts with other subjects
Reliability	Dependability, stability, consistency, predictability, accuracy	Consistency	Whether the findings of an inquiry can be repeated if the inquiry were replicated with the same or similar subjects and context.
Objectivity	Unbiased such that there can be inter-subjective agreement	Neutrality	Findings of an inquiry are determined by the subjects and conditions of the inquiry and not the biases, motivations, interests, or perspectives of the inquirer.

Techniques to support external validity in qualitative research include triangulation, thick descriptions, SME feedback, and corroboration. These all strengthen generalizability in qualitative research design and align with Duff (2006), Golafshani (2003), and Patton (2002). The goal of this research was to produce a framework to assess R&D PMS implementations with the scope delimited to R&D organizations at the enterprise level. It is necessary that the framework be generalizable within this context. Table 8 identifies the ways in which the methodology addresses the recommendations in the literature.

Table 8: Generalizability strength in the methodology
(adapted from Duff, 2006; Leedy & Ormrod, 2010)

Qualitative Strengthening		Dissertation Methodology
A real life setting (Leedy & Ormrod, 2010)	✓	Interviews conducted with SMEs
A representative sample (Leedy & Ormrod, 2010)	✓	Interviews conducted in multiple public and private R&D organizations of different contexts.
Having an aggregation of multiple-case or multiple-site studies: triangulation (Duff, 2006)	✓	Interviews and framework validation conducted at multiple sites. Results to be integrated and compared with data from scholarly literature.
Thick description (Duff, 2006),(Leedy & Ormrod, 2010)	✓	Interviews included semi-structured questions.
Extensive time in the field (Leedy & Ormrod, 2010)	✓	Emersion in the literature and collection of data in the field over a 2 year period. The researcher has worked in the area of R&D for over a decade.
Feedback from others (Leedy & Ormrod, 2010)	✓	Preliminary conclusions vetted with institutional colleagues in both university and organizational settings.

One of the value strengths of qualitative research is that one can get a wealth of information from a smaller sample size through a deeper immersion into the data from the available sources. This aligns with Patton (2002) who notes that "the validity, meaningfulness, and insights generated from qualitative inquiry have more to do with the information richness of the cases selected and the observation/analytical capabilities of the researcher than with the sample size" (p. 245).

3.1.2 Reliability. Leedy and Ormrod (2010) define reliability as the "consistency with which a measuring instrument yields a certain result when the entity being measured hasn't changed" (p. 29). For this dissertation, a grounded theory research design has been used to provide a reliable methodology to inform the development of this research's framework. Grounded Theory is a research approach that "provides a detailed, rigorous, and systematic method of analysis" (Jones & Alony, 2011, p. 96). In a grounded theory research design, the researcher develops an abstract theory of processes and interactions and the theory development is said to be grounded in fieldwork which is conducted in a practical setting (Creswell, 2009; Patton, 2002). It builds the theory by using a constant comparison of data to connect both inductive and deductive knowledge about a phenomenon by utilizing a set of standardized coding procedures (Patton, 2002). The approach is regarded as ontologically post-positivist although the approach has been adapted to fit constructivism, post-modernism and situational analysis as use of the GTM has been applied to increasingly diverse areas of research (Wilson, 2012). Procedures guide research such that a theory can be developed using the feedback from multiple participants (Corbin & Strauss, 2008; Wilson, 2012).

Corbin and Strauss (1990) propose canons and procedures so that the research can be systematically evaluated. Corbin and Strauss (1990) offer what they deem to be procedures to guide the grounded theory methodological approach.

1. Data collection and analysis are interrelated processes
2. Concepts are the basic units of analysis
3. Categories must be developed and related
4. Sampling in grounded theory proceeds on theoretical grounds
5. Analysis makes use of constant comparisons
6. Patterns and variations must be accounted for

7. Process must be built into the theory
8. Writing theoretical memos is an integral part of doing grounded theory
9. Hypotheses about relationships among categories should be developed and verified as much as possible during the research process
10. A grounded theorist need not work alone
11. Broader structural conditions must be analyzed, however microscopic the research

The analytic process involves open coding, which iteratively breaks down data, axial coding, which relates categories to their sub-categories, selective coding, which relates all categories to a core category, and theory generation (Corbin & Strauss, 1990). Leedy and Ormrod (2010) detail the steps of the methodology as follows:

1. ***Open coding***. *The data are derived into segments and then scrutinized for commonalities that reflect categories or themes. After the data are categorized, they are further examined for properties – specific attributes or subcategories – that characterize each category. In general, open coding is a process of reducing the data into a small set of themes that appear to describe the phenomenon under investigation.*
2. ***Axial Coding***. *Interconnections are made among categories and subcategories. Here the focus is on determining more about each category in terms of*
    a. *The conditions that give rise to it*
    b. *The context in which it's embedded*
    c. *The strategies that people use to manage it or carry it out*
    d. *The consequences of those strategies*

The researcher moves back and forth among data collection, open coding, and axial coding, continually refining the categories and their interconnections as additional data are collected.

3. ***Selective coding**. The categories and their interrelationships are combined to form a story line that describes "what happens" in the phenomenon being studied.*
4. ***Development of a theory**. A theory, in the form of a verbal statement, visual model, or series of hypotheses, is offered to explain the phenomenon in question. The theory depicts the evolving phenomenon and describes how certain conditions lead to certain actions or interactions, how those actions or interactions lead to other actions, and so on, with the typical sequence of events being laid out. No matter what for the theory takes, it is based entirely on the data collected.* (p. 143)

The grounded theory methodology provides the basis for validity when studying socially embedded subject areas where the understanding of phenomena emerges through emersion in the data (Jones & Alony, 2011). The steps listed above "provide a structured and relatively systematic way of boiling down a huge body of data into a concise conceptual framework that describes and explains a particular phenomenon" (Leedy & Ormrod, 2010, p. 143). Upon completion of this process, the grounded theory can be developed.

While grounded theory methodology has been used as the basis for validity within this qualitative research study, triangulation has functioned as another means to increase the reliability of the research (Golafshani, 2003). Triangulation of data gleaned from interviews and literature has been used to increase reliability of this dissertation's research framework for systems-based R&D PMS implementation assessment.

3.1.3 Triangulation. The dissertation utilized triangulation to reinforce the credibility of its results. Lincoln and Guba assert that triangulation is a vital component to establishing trustworthiness and is necessary for interpretations made by research to be deemed credible (1985). The term triangulation refers to the use of "multiple sources, methods, investigation, and theories" (Lincoln & Guba, 1985, p. 305) to determine the reliability and validity of data. For this dissertation, relevant literature resulting from an extensive literature search has been compared to identify common themes associated with effective PMS implementations. Multiple literary data sources, from multiple journals, were aligned to the findings of the GTM.

Interviews were conducted with managers of R&D organizations to identify themes associated with effective PMS implementations. These included samples from both public and private sector R&D organizations. Although the output framework of this dissertation was focused on the enterprise level, the interviews were conducted with both managers that develop and assess the R&D performance measures and managers who are charged with producing results relative to the measures. Collecting information from these managers, working at different levels with an organization's PMS, has ensured that the resultant R&D PMS implementation assessment framework considers multiple worldviews. This helped to identify areas of strength within the existing system, dysfunctional areas and issues that may be leading to unintended consequences. This is consistent with the systems-based approach described in Chapter 2.

Literature was triangulated with the data gleaned from the interview process during the theoretical derivation of the operational characteristics in Section 4.2. The interview data was used to derive the operational characteristics, however, the synthesis of the four literature threads, performance measurement in R&D, performance measurement systems, performance measurement assessment, and systems theory, were used to provide additional perspectives to the data and as another tool that could be used to ensure theoretical saturation. Further, understanding if there is a disconnect between literature coverage and practical PMS implementation was of interest to this researcher. Once triangulated, these two data sources were used, along with the systems alignment, to produce the R&D PMS implementation assessment framework, described in Chapter 4, generalized within the context of enterprise level R&D organizations.

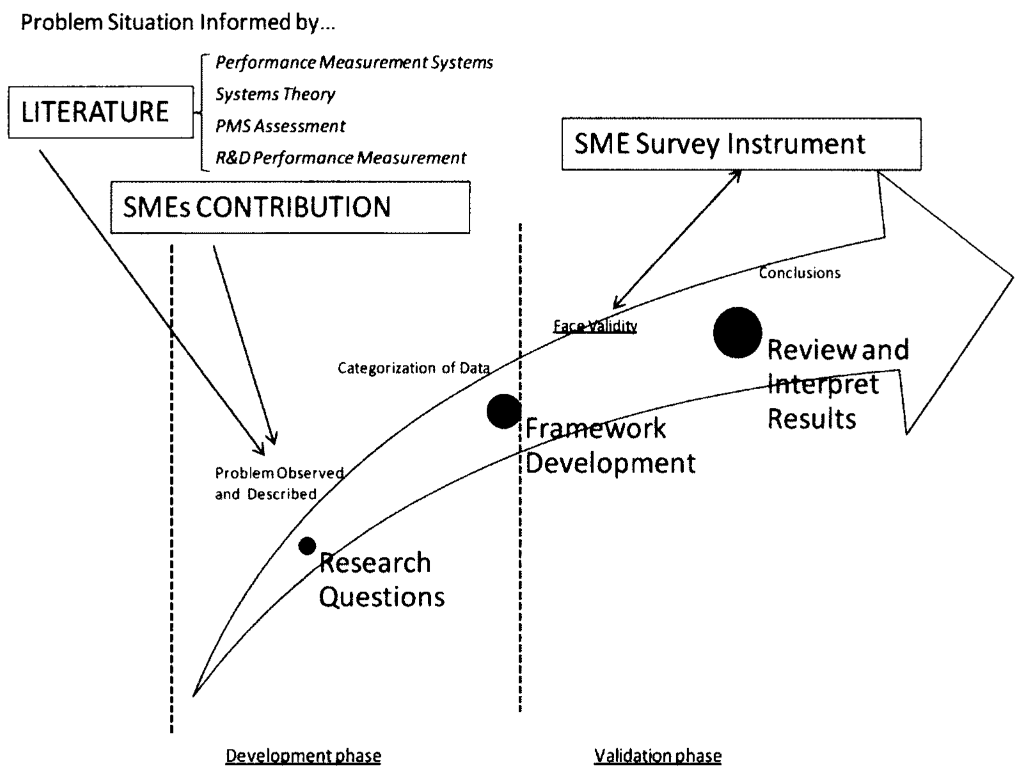
3.1.4 Researcher's role. Qualitative methods require the researcher to define relevant data, establish and administer data collection procedures, make determinations and draw conclusion from data. This allows for some level of subjectivity as the researcher interprets the data through his or her own personal lens and introduces the potential for issues in the data collection and analysis process resulting from "personal biases, values and personal background"(Creswell, 2009, p. 177). The following discusses the background of the researcher of this dissertation.

The researcher of this dissertation is a manager within a government funded national laboratory; an R&D organization conducting basic energy science research for the U.S. Department of Energy. This provided the researcher the opportunity to access and communicate with peers about strengths and weaknesses associated with the performance measurement systems utilized both within the organization and enacted by the DOE to monitor performance of its various national labs. As a student at Old Dominion University, the researcher also had frequent discussions about performance measurement within the university and organizational contexts. The research associated with this paper has been approached from a neutral perspective. Still the researcher's immersion in the field of R&D has helped to shape some thinking about the way in which people behave within the context of PMS implementations in R&D organizations.

3.2 RESEARCH DESIGN

The research design of this dissertation has been divided into a developmental phase and a validation phase. As discussed previously, the methodology has utilized a grounded theory approach to develop a thorough understanding of the problem domain. Figure 6 describes the methodology that has been used to guide the research as it moves from its inception to conclusion. The following sections details the specific methods used for data collection and analysis, which was used to inform and develop the different phases of the research design methodology.

Figure 6: Research Design



3.2.1 Data collection. Three instruments have been used to collect the data required to answer the questions posed in this dissertation. These include literature synthesis, interviews, and surveys. Each method of data collection is tied to specific research questions such that their associated outputs can inform the development of the assessment framework. Table 9 details the data collection method(s) associated with each of the research questions. The details of how each data collection method was utilized to address the research questions are discussed in the following sections.

Table 9: Data collection methods used to answer research questions

Research Question	Sub-problem	Data Collection Method		
		Literature	Interviews	Surveys
1. What operational characteristics are necessary for an effective R&D performance measurement system at the enterprise level?	a. Determine the core PMS functions	X	X	
	b. Tailor PMS functions to R&D organizations	X	X	
2. What systems theory concepts apply to the assessment of performance measurement systems in an R&D environment?	a. Identify systems principles that apply to R&D PMSs	X		
	b. Align the systems-based approach to the assessment framework	X	X	
3. How can R&D performance measurement system implementations be assessed from a systems perspective?	a. Develop the assessment framework	X	X	
	b. Face validate the assessment framework			X

3.2.2 Systems-based approach. The systems principles and axioms from Adams et al. (2014) have been used as a basis for the systems-based approach to the study. The systems axioms, formed from the propositions in Table 6, provided guidance to the research so that reviews of existing frameworks and field interview questions were designed in a holistic way that takes into account the complexity of social systems. Used in this manner, the systems axioms and principles were not contrary to a grounded theory methodology in that they "shed light on the question under study" (Corbin & Strauss, 1990). A set of reflexive questions, based on systems axioms, has been developed to structure thinking from a systems-based perspective while reviewing data about R&D

PMS implementations. These questions are as follows:

1. The Centrality Axiom states that *central to all systems are two pairs of propositions; emergence and hierarchy, and communication and control.*
    a. Does the PMS have a way to understand its changing conditions and provide meaningful feedback?
2. The Contextual Axiom states that *system meaning is informed by the circumstances and factors that surround the system.*
    a. What is different about R&D PMSs? Public vs. Private?
3. The Goal Axiom states that *systems achieve specific goals through purposeful behavior using pathways and means.*
    a. Does the PMS provide the appropriate means by which an organization can improve?
4. The Operational Axiom states that *systems must be addressed in situ, where the system is exhibiting purposeful behavior.*
    a. How does the information from SME interviews inform the research concerning strengths and weaknesses of PMS implementations?
5. The Viability Axiom states that *key parameters in a system must be controlled to ensure continued existence.*
    a. What parameters are required to ensure that a PMS can operate efficiently over time?

6.The Design Axiom states that *system design is a purposeful imbalance of resources and relationships*.

a. How are performance measures designed, how are they monitored, and how do they evolve?

7.The Information Axiom states that *systems create, possess, transfer, and modify information*.

a. Does the organization's infrastructure support the PMS in terms of data collection, transfer, and feedback so that the system can learn and improve?

The goal of the study was not to compile a comprehensive list of performance measurement system implementations behavior relative to all existing systems principles. Rather, the goal was to create a suitable means by which the strengths and weaknesses of R&D PMS implementations can be probed from a systems perspective. The questions, built from the axioms, offer a systems lens through which characteristics that are unique to R&D performance measurement systems can be identified. These unique characteristics can them be cross referenced with the systems principles and definitions from which the axioms were built. This provides a traceable mechanism by which the R&D performance measurement system implementation research can be evaluated from a systems approach.

3.2.3 Literature categorization and synthesis. The literature review in this dissertation has shown that extensive written documentation exists to support concepts associated with systems theory, PMS frameworks, R&D performance measurement, and performance measurement assessment. The goal of this dissertation has been to effectively synthesize this data to develop a systems-based assessment framework. A continuous effort was made to investigate available literature as more was understood and as questions arose throughout the research effort. The data were reviewed based on the GTM identified codes which were used to create a greater depth of understanding with respect to categories and themes emerging during the initial step of the data analysis process.

A literature search was conducted to provide data relevant to the research questions in this dissertation. A keyword list was developed based on the subject focus of this research including performance measurement, performance measurement systems, R&D, PMS assessment and systems science. The keyword list included the following terms:

- Performance measurement
- Performance measures
- Measures of effectiveness
- Measures of performance
- Performance measurement systems
- Balanced Scorecard
- R&D
- Research and development
- Assessment of PMS implementations
- Performance measurement system effectiveness

Results of the search were reviewed and relevant articles were identified. The criteria used to evaluate if literature was relevant included determining if they were germane to the subject area, found in published books or peer reviewed journals, and offered a perceived contribution to this research. The search did not prescribe a specific research protocol conducted by authors in the literary field. Both qualitative and quantitative studies were given consideration for inclusion.

As a result of the initial keyword search, conducted using Google Scholar, several journals were identified that offered significant contributions to this dissertation's research area. It became immediately clear that there was an expansive amount of data that exists on the research subject. For example, Neely(2002) notes that new articles or works in the area of performance measurement have appeared at a rate of one every five working hours since the mid 1990's. Rather than conducting an exhaustive search of the literature, a purposive search was conducted. Several journals were found to contain essential state-of-the-art literature in the performance measurement subject area, specifically articles by the authors of the Balanced Scorecard and Performance Prism, articles on the area of performance measurement in R&D, and articles building on the foundational work of Dixon's 1990 performance measurement questionnaire in the area of PMS assessment. These included R&D Management, Research and Technology Management, International Journal of Productivity and Performance Management, Harvard Business Review, and International Journal of Operations and Production Management. To validate the usefulness of these journals, the literature was probed to identify expected impact from each. Results of the validation are as follows:

- **R&D Management**
- **Research Technology Management**
    - Both considered Top-10 journals based in Technology and Innovation

Management (Linton & Thongpapani, 2004)

- **International Journal of Productivity and Performance Management (IJPPM)**
    - Considered a Top-50 ranked in strategy and management by SRJ (2007)
- **Harvard Business Review**
- **International Journal of Operations and Production Management**
    - Both considered to be top journal "publishing a breadth of both empirical and modeling research"(Petersen, Aase, & Heiser, 2011)

A more in depth search was done on these journals, from 1990 to present, to identify additional relevant literature to further inform this dissertation. The selected articles were then studied to identify major themes. Review of this sample identified articles from other journals and books which were reviewed and compiled into a collection of over 70 documents. These have served as coding confirmation sources for the operational characteristics identified during the GTM and used for the systems-based assessment framework for R&D PMSs. The breakdown of the literature is as shown in Table 10. It is important to note that this breakdown represents the main topic each document is associated with although much of the literature overlaps into other topic areas. The tally is based on the main contribution of the article or book as determined by the author of this dissertation. However, the information in some articles adequately spans different content areas. For example, several articles touch on system-based concepts without detailing a structured systems-based approach to the development of their performance measures or frameworks. Others articles discuss both performance measurement system frameworks and R&D performance measurement.

Table 10: Breakdown of literature by number of articles/subject

Number of literary documents per content area	PMS	PM & R&D PM	Systems	PMS Assessment
	19	24	15	12

This represents the literature-based data that has been used to augment the data from interviews and surveys described later in this chapter. This is also representative of the academic view of the state-of-the-art of the literature relevant to this dissertation. These articles were used to triangulate with interview data during the theoretical derivation of the operational characteristics. The literature itself was not used to create the codes associated with the grounded theory methodology. However, if significant differences were identified between the GTM derived operational characteristics and the guidance in literature these differences would have been noted and discussed. Results of the research, detailed in Chapter 4, will identify the specific operational characteristics and their associated attributes and how the literature was shown to align well with the research findings. The next section will discuss the interview process and the reasoning behind compiling a data set from the practitioner's viewpoint for this research.

3.2.4 Interviews. Interviews provide a way for a researcher to gain knowledge and insight into a particular subject being studied. This offers a way for the researcher to gain multiple perspectives about a subject of interest. The goal of this dissertation's interviews has been to gain qualitative knowledge to help shape the understanding of requirements, challenges, and pitfalls associated with R&D PMS assessment. These qualitative interview questions were semi-structured and flexible to allow the respondent to provide both planned and unplanned information (Leedy & Ormrod, 2010). This process provided the researcher of this dissertation with a deeper understanding of practical R&D PMS implementations.

Interview questions were developed to gain pragmatic knowledge pertaining to the research questions of this dissertation. These questions were submitted to Old Dominion University's (ODU) Institutional Review Board (Appendix A) and were deemed to not constitute human subject research and therefore not require IRB approval or exempt status. The following questions were used to guide the interviews:

1. How is your organization's Performance Measurement System built to fit its context?
2. How often are performance measures updated?
3. How does the PMS account for new conditions that occur in the system?
4. How is performance measurement information shared?
5. How does your organization currently develop performance measures?
6. What are the strengths of the way measures are selected?
7. What are the weaknesses associated with measures being developed?
8. How does your organization use information from performance measures?
9. What infrastructure does your organization use to support your PMS?
10. What value does the performance measurement system add to the organization?
11. What are the strengths of the PMS that the organization has in place?
12. What could be improved?
13. How does the organization act on information gained from performance measurement?

14. Does the system support the organization's mission?

3.2.5 Subject matter expert inclusion criteria. For this dissertation, interviews were conducted as part of the GTM. This provided feedback from practitioners that were used to derive the operational characteristics for the R&D performance measurement systems. The interview questions have been identified above. The interviews involved practitioners chosen for their knowledge and experience of PMS implementations.

The research utilized six regionally based R&D organizations in the interview process. Five R&D organizations from the public sector and two from the private sector were included. The associated coding process, detailed in this chapter, was used to identify themes in the interview responses. The sample size was determined during the data collection process based on theoretical saturation (Thomson, 2011). However, the number of interview participants available with specific knowledge in R&D PMS was limited. Fewer participants are often required if the researcher is able to collect more usable data from each participant (Thomson, 2011) and, based on a literature review on grounded theory studies conducted by Thomson, as few as five participants have been used before reaching theoretical saturation. Based on the focus of the questions and the expertise of the interview participants, the number of interviews was expected to be approximately 10 to 15 with a minimum of five. Five interviews were conducted before beginning to evaluate theoretical saturation. Theoretical saturation did occur earlier than expected, taking place after completion of the seventh interview. For the interviews, the following inclusion criteria were used to select SME participants:

- **Organization maturity**: Organization must have existed and used a PMS for at least five years.
- **Organizational designation**: The organization must be an R&D organization of sufficient size (>50 employees). Both public and private organizations included.
- **Individual Experience**: two or more years of work (individually or as part of a team) experience associated with R&D and PMSs. Also, middle level managers tasked with fulfilling the requirements of the PMS implementation have been included for triangulation.

3.3 DATA ANALYSIS

The NVivo software package was used to document and track the data collection and analysis processes. The tool is designed to organize and analyze qualitative, unstructured research data such as transcribed interviews. For this dissertation, the transcribed interview data were imported into NVivo as individual text units. Coding was started after the second interview was completed. The NVivo software allows the researcher to save the codes as "nodes" which are used as the basic units of data within the software. The software offers several tools to assist the researcher including auto-coding and text search functions. These features became more useful as the process became more complex as more data were introduced during the open coding phase of the grounded theory analysis. Also, the software allows the researcher to combine, rearrange, and split coding sections as new data is introduced and understood. This is a significant help to the emergent theory associated with GTM. Data, in the form of interviews, were numbered sequentially to ensure anonymity of the interview participants. Specific references to interviews in this research have been referred to only by the interview sequence number. The following paragraphs describe the qualitative process and thinking used throughout the analysis phase.

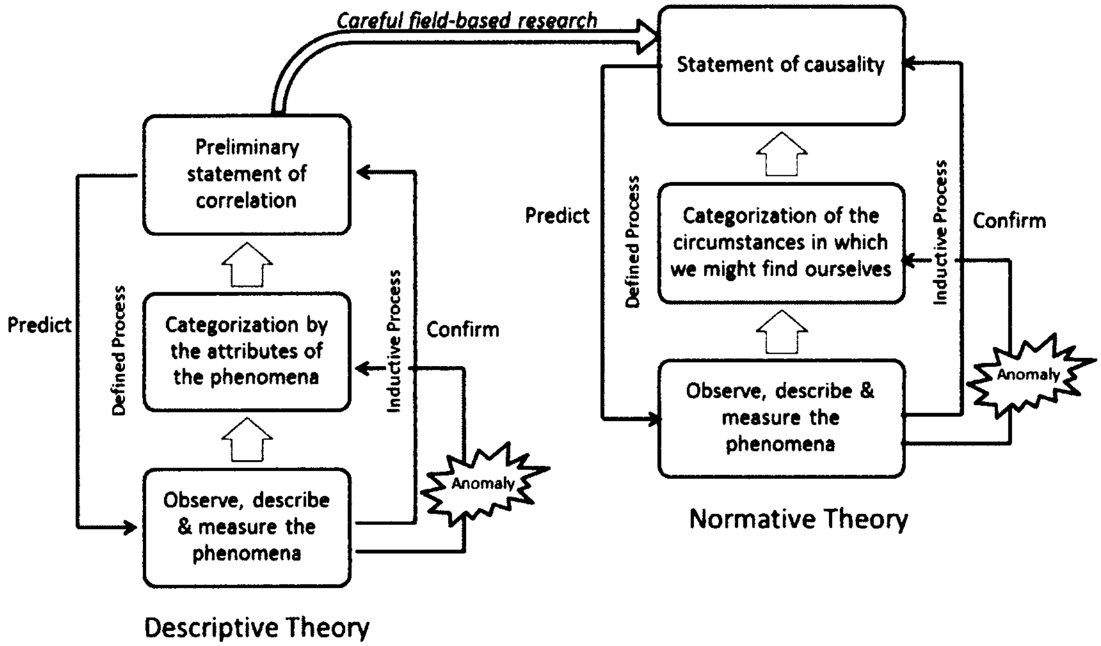
3.3.1 Analysis methodology. Creswell (2009) articulates that the process of data analysis involves "conducting different analyses, moving deeper and deeper into understanding the data, representing the data, and making an interpretation of the larger meaning of the data"(p. 183). Patton (2002) describes establishing theory in qualitative research as "connecting induction and deduction through the constant comparative method, comparing research sights, doing theoretical sampling, and testing emergent concepts" (p. 125). In qualitative research, it is through this understanding that the researcher seeks to build the research theory. Carlile and Christensen (2004) assert that there are two stages in which theory transitions: the descriptive stage and the normative stage. Both of these stages contain three steps which direct the formation of the theory. The three steps of the descriptive stage are:

1. **Observation** – The first step of the process in which the researcher carefully takes measurements of phenomena that is used to make a description of what is observed.
2. **Classification** – In this stage the researcher seeks to categorize the phenomena based on their associated attributes in an attempt to simplify and organize it in a way that will show consequential relationships (often referred to as frameworks).
3. **Defining Relationships** – the third stage involves building a model by associating the category-defining attributes with observed outcomes. (Carlile & Christensen, 2004)

Once the three steps of the descriptive stage are complete, the researcher can say that the model is predictive of average cases of a phenomenon. However, the model cannot yet be known to successfully predict results in a specific situation or setting. For this, the researcher needs to proceed to the normative stage of theory development as shown in Figure 7.

The normative stage seeks to refine the model to accurately describe situational-dependant conditions. The researcher uses the same three steps noted above to evaluate different circumstances that either confirm or refute their causal model. A circumstance that refutes the model is called an anomaly. Anomalies are investigated to determine what caused them to produce a different outcome, the model is refined, and the three step process is repeated. When this process has been completed for all identified scenarios, the process of moving from the descriptive stage to the normative stage can be considered complete (Carlile & Christensen, 2004).

Figure 7: Steps of the descriptive and normative theory process
(adapted from Carlile & Christensen, 2004, p. 6)



For this dissertation, theory was developed from information gleaned from both the scholarly literature and practitioner and academic interviews and surveys. These informed the descriptive theory. Surveys designed to validate the assessment framework have been used to provide a first step towards development of a normative theory. However, a series of case studies will be required to complete the transition from descriptive to normative theory development. This provides an opportunity for future research on this topic. The two perspectives, those of practitioners and academics, holistically capture the essential elements associated with effective R&D performance measurement systems.

3.3.2 Data categorization. Data coding was used to identify themes and codes utilizing both interviews and literature. The coding utilized the following process:

1. Create a general sense of the literature or interview data associated with each thread.
2. Determine underlying meanings and ideas within several data sources.
3. Create a list of topics. Cluster where appropriate.
4. Review the literature or interview data again using codes as abbreviations for the topics. Identify any new topics.
5. Turn topics into categories using descriptive names and group where possible.
6. Create a final code abbreviation for each category and alphabetize the list.
7. Dissect the literature or interview data and group it by category to perform the initial analysis.
8. Re-code data where necessary.

(adapted from: Creswell, 2009, p. 186)

The scholarly literature was reviewed first. Based on knowledge gained from the literature review, relevant articles, based on a qualitative assessment, were determined for the four areas previously identified as essential to informing the systems-based R&D PMS implementation assessment framework. These are performance measurement system frameworks, R&D performance measurement, PMS assessment, and systems theory. The first three areas are associated with R&D PMS assessment and appeared to be obvious, germane, threads to explore for this dissertation's research. The fourth thread, systems-theory was explored based on the research hypothesis that systems theory would inform the systemic coverage associate with R&D PMS implementation assessment. The criteria for inclusion of the article was that each needed to be published in a published book, peer reviewed journal or magazine, be associated with one of the four thread (i.e. support the research findings), and represent a purposive sample of articles.

The interview data were coded using the grounded theory methodology. Although the original intent was to use a set of predetermined codes from literature, the nature of the GTM required that the researcher develop the theory of operational characteristics independent of the literature. Once complete, a systematic alignment to literature was conducted to ensure that the axial categories derived from interviews addressed the areas identified in the literature. This provided a significant contribution to the performance measurement research area in that it synthesized practitioner data into categories of operational characteristics present in successful R&D organizations. The data analysis identified emerging categories and their associated codes detailed in the following chapter.

3.4 ETHICAL CONSIDERATIONS

As discussed earlier in this chapter, this dissertation uses data derived from literature and gained through interviews with practitioners. Survey data given to practitioners were used to validate the output of this dissertation, the R&D PMS implementation assessment framework. Each of the areas required the author of this dissertation to adhere to high ethical standards so as to accurately represent the intentions of the persons supplying the data.

Data compiled from the literature were represented in context so as to best represent the ideas and opinions of the literature's author. A thorough review of the literature was completed so that this dissertation's author has the required background to properly represent the various ideas found throughout the literature.

Interviews presented an opportunity to collect varied and rich information from the viewpoint of the individual participants. Surveys provided information needed to validate the framework and identify opportunities for improvements. To maintain high ethical standards, an informed consent form was completed and reviewed for the interviews to ensure participant rights were protected while they participate in the data collection process. Interview questions and consent forms were reviewed by the appropriate persons based on the processes established by Old Dominion University and the university's IRB (Appendix A). However, the research was not deemed to constitute human subject research and therefore did not require IRB approval or exempt status.

CHAPTER 4

RESEARCH RESULTS

As presented in Chapter 1, the purpose of this study was to develop a systems-based framework for the assessment of performance measurement system implementations in R&D organizations. This framework is meant to be applied at the enterprise level by industry practitioners to assess their PMS implementation. It can be used to determine if an organization's performance measurement system has been constructed to include the operational characteristics deemed by this research as being both necessary for an R&D performance measurement system and aligned with systems theory. Three research questions were framed specifically to address the study's goal of developing a framework for the assessment of performance measurement systems for R&D organizations. Specifically, the research was focused on addressing three questions:

1. What operational characteristics are necessary for an effective R&D performance measurement system at the enterprise level?
2. What systems theory concepts apply to the assessment of performance measurement systems in an R&D environment?
3. How can R&D performance measurement system implementations be assessed from a systems perspective?

The research results begin with developing the answer to the first question and identification of the operational characteristics. A grounded theory method was used to analyze data derived from semi-structured interviews. The research methodology that was employed in conducting the interviews, collecting and analyzing the qualitative data, triangulating results with literature, and developing the theoretical construct was described in Chapter 3.

This chapter presents the results of the grounded theory method used to establish the operational characteristics, a systems alignment to the operational characteristics, and the systems based assessment framework. The research methods and results will be presented in the following order:

1. The framework for semi-structured interviews is described.
2. An overview of the grounded theory method (GTM) analysis findings, described as operational characteristics, and a detailed description of the associated attributes.
3. A discussion of the alignment between results of the grounded theory analysis and systems theory perspectives.
4. The systems-based framework for R&D PMS implementation assessment.

The results presented in each element will provide the building blocks for the successive elements. For example, Elements 1 and 2 will address the first research question. Element 3 will address the second research question building on the results from Elements 1 and 2. A synthesis of the findings from the first three elements will be used address the third research question in Element 4.

4.1 THE FRAMEWORK FOR SEMI-STRUCTURED INTERVIEWS

Semi-structured interviews were conducted as the primary source for qualitative research data. Initial line-by-line coding, using the grounded theory method, was begun after the first interview and continued throughout the interview process. As new concepts emerged, the data was reevaluated to ensure the alignment between the data and the emergent theory. Interviews and analysis continued until no new conceptual characteristics were being found and theoretical saturation was reached (Charmaz, 2008).

4.1.1 Interviews and SME criteria. The interviews utilized a series of structured questions as identified in Chapter 3. The initial estimate for the interview was believed to be approximately 30 minutes. However, based on the nature of GTM, additional questions were sometimes asked to probe deeper into the answers provided. In all cases, the interviews ran longer than expected, with most approaching one hour. This additional information allowed the researcher of this dissertation to develop a stronger understanding of the context and reasoning associated with the interviewee's answers.

The initial interviews were conducted with colleagues of this dissertation's researcher. At the conclusion of the interview, the SME was asked to identify another SME that he or she felt would be able to both meet the SME inclusion criteria and add value to the research. In each case, the SME was able to provide another contact. This made the research interview process straightforward and allowed for collection of the required information. As detailed in Chapter 3, SME interviewees were identified based on the following criteria for inclusion:

- **Organization maturity**: Organization must have existed and used a PMS for at least five years.
- **Organizational designation**: The organization must be an R&D organization of sufficient size (>50 employees). Public and private organizations will both be included (at least two of each).
- **Individual Experience**: two or more years of work (individually or as part of a team) experience associated with R&D and PMSs.

Table 11 summarizes the SMEs qualifications based on the described inclusion criteria.

Table 11: Subject Matter Expert Qualification Summary

Interview #	Professional Experience	5+ years using PMS	R&D Org Size	Educational Background	Current Position	Professional Background	Org Type
1	11	✓	500	MA in Human Resources & Organizational Development	Division Manager	Division lead for R&D lab. Previous: Industry organizations (2 Fortune 500)	Public
2	36	✓	120	Ph.D in Nuclear Eng	R&D Division Manager	Aerospace industry R&D activities. DoE program management. Group leader during lab construction for 5 years 120 people, $120M, division deputy management for 14 years. Associate director of lab for 4 years.	Private
3	30	✓	20,000	MSEE (Quantum Electronics), BS Nuclear Engineering	R&D Project Manager	R&D Project Management ($50M-$100M project level). Integrate performance management experience DOD, DOE, NASA, and as contractor).	Public
4	12	✓	2,000	PhD Experimental Psychology	Director of Research Development	University (1,500-2,000 employees, $104M in research funding); Prior University (5,000 employees, $510M in research funding)	Public
5	30+	✓	500	MBA	DOE Contracting Site Officer	Site office representative for DOE	Public
6	10	✓	2,000	MBA	Project Manager	Medical equipment supplier, System evaluation (Navy)	Private
7	15	✓	10,000	PhD in Microbiology & Immunology	VP, Global Academic & Research Relations	Experience in pharmacology, academia, and publishing/research analytic.	Private / Public

The qualitative data gained from the interviewees provided significant pragmatic data for R&D performance measurement. These interviews extended beyond the mechanisms that are used to build a PMS to include their views on the human aspects of building and working with performance measurement as a system. IRB documentation and interview protocol information can be found in Appendix A. The next section presents an overview of the R&D PMS operational characteristics that emerged during the analysis

4.2 R&D PMS OPERATIONAL CHARACTERISTICS

This section describes the R&D operational characteristics that emerged during the GTM analysis process. Following the steps of the GTM (Corbin & Strauss, 2008), 12 axial codes were constructed based on the results of the open coding. Selective coding was then conducted to identify any "meta-characteristics". However, it became apparent to this researcher that further refinement of characteristics to meta-characteristics would create elements that are too abstract to operationalize. Implementation confusion (Tangen, 2005; Van Ake et al., 2005) and problems with existing framework resolutions (Ojanen & Vuola, 2003) have been noted in literature as reasons for PMS implementation failures. The purpose of this study is to create a framework for assessment for R&D PMS implementations. Therefore, meta-characteristics will not be presented as a part of this study but may be useful to explore in future research. Based on the researcher's decision, the granularity of the axial codes provided a better resolution to describe the operational characteristics and effectively inform the identified problem situation. The results presented will detail each of the axial codes, which shall be called operational characteristics, and the open codes from which they arose, called attributes. The section will present the operational characteristics alphabetically, with no ranking order implied. The following characteristics answer the first research question:

- What operational characteristics are necessary for an effective R&D performance measurement system at the enterprise level?
    - ✓ **Balancing** – refers to the way in which the PMS must create harmony in the context of time, perspectives, resources, and measurements
    - ✓ **Clarifying** – refers to the system's ability to construct and articulate meaningful measures as well as monitor and address issues of uncertainty
    - ✓ **Evaluating** – refers to the methods used to compare and understand measurement results
    - ✓ **Evolving** – refers to system's ability to change in response to emergent conditions or understanding
    - ✓ **Humanizing** – refers to the human aspects and considerations associated with R&D PMS implementations
    - ✓ **Improving** – refers to the system's ability to make positive changes as a result of measurement results and emergent conditions
    - ✓ **Incentivizing** – refers to the way in which the system drives compliance with the PMS
    - ✓ **Projecting** – refers to the organization's ability to project its identity throughout the PMS
    - ✓ **Servicing** – refers to the system's ability to meet the needs of their external stakeholders so as to maintain the organization's existence

- ✓ **Sharing** – refers to the dissemination of performance measurement information and results
- ✓ **Supporting** – refers to the organizational tools and management that must be present for the PMS to function
- ✓ **Tailoring** – refers to the way in which an organization creates their contextually specific PMS.

As stated, these operational characteristics were the results of the axial coding of attributes derived from the GTM. The next section will detail the attributes from which each of the operational characteristics emerged and the associated supporting literature. A more detailed definition of each of the operational characteristics will also be provided.

4.2.1 Detailed definitions of attributes. The following section presents the operational characteristics in greater detail and the specific attributes from which they emerged. The initial research stage involved analyzing, segmenting, and categorizing specific themes in the interview data (Corbin & Strauss, 2008). Using the data themes, each attribute was derived and coded as an emergent concept. The themes from the interview data that were used to derive the attributes and references to associated literature are provided in this section's detailed descriptions. The axial codes arose as the interconnections between attributes were realized.

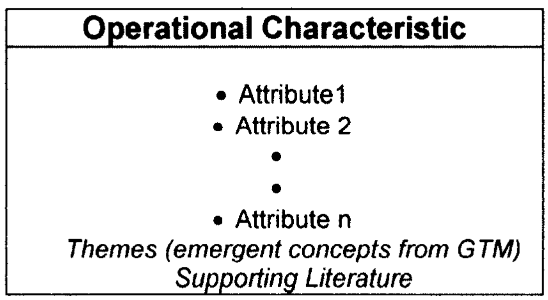
Following the GTM axial coding, a criterion for inclusion was determined to validate the strength of the emergent attributes. The specific criteria for each attribute are that it was:

- derived from the GTM,
- represented in at least 3 of the 7 interviews (see Appendix C),

- supported by at least 3 literary references,
- and associated with a single operational characteristic.

To add clarity to upcoming data, a layout of the operational characteristic and the associated attributes will precede the detailed description as shown in Figure 8. A summary of all operational characteristics and their associated attributes can be found in Appendix B. In the following discussion, the ordering of attributes is listed alphabetically with no implied ranking.

Figure 8: Operational Characteristic detailed layout diagram



4.2.1.1 ***Balancing.*** Balancing refers to the way in which the PMS must create harmony in the context of time, perspectives, resources, and measurements. Performance measurement requires resource investment. These resources can be wasted if the system is overloaded with measures, or when quantitative measures are used when qualitative reasoning is required, or when short term measures start to overwhelm the R&D function's long term mission. Failing to address balancing can lead to the investment being wasted on a failed system (Kaplan & Norton, 2007; Kerssens-van Dronglen & Cook, 1997; Neely & Bourne, 2000).

Figure 9 describes the attributes identified during the open coding phase of the

GTM that are associated with the operational characteristic *balancing.*

Figure 9: Balancing - Detailed layout diagram

Balancing

- Investment Time and Resources
- Multiple Perspectives
- Qualitative and Quantitative Measures

The attributes contributing to the operational characteristic *balancing* are discussed in the following paragraphs.

Investment of Time and Resources – The resources invested into performance measurement must be appropriate to the desired outcomes of the system. For private organizations, there is a need to balance PMS costs against expected revenues and return on investment (ROI). Public organizations must balance PMS costs against expected budget and return on mission (ROM). PMSs for both public and private organizations must adhere to mandated regulatory requirements. This is consistent with the dimensional approach to public and private sector designations.

Themes identified include dysfunctional behaviors such as spending more on project planning than project execution, spending more time and resources on tracking metrics when money is tight, creating a system so complex it cannot be understood and, conversely, eliminating so many metrics that sound decisions cannot be made. Interviews 1, 2, 3, 4, 5, and 7 identified this attribute. Literature supporting this characteristic included Boland and Fowler (2000), Keating et al., (2009), Paparone and Crupi (2006), and Szakonyi (1994b).

Multiple Perspectives – Organizations need to consider multiple perspectives when defining and analyzing their metrics. Backwards looking accounting perspectives are insufficient (Bourne et al., 2003; Kaplan, 2008; Meyers & Hester, 2011). R&D organizations must seek to balance autonomy to maintain their identity and the primary stakeholder's desires as the organization seeks to maintain their funding. The expectations of the primary stakeholder may differ from the R&D organization. This may manifest itself in terms of a short term focus.

Themes include stakeholders imposing inappropriate measures, disagreements over ratings, aligning viewpoints during reviews, weighing public perception, and rating subjectivity in R&D. Interviews 1, 2, 3, and 5 identified this attribute. Literature supporting this characteristic included Bourne et al. (2003), Kaplan (2008), Meyers and Hester (2011), and Ojanen and Vuola (2003).

Quantitative and Qualitative Measures – The nature of R&D is that an organization is working with something that is not yet understood. The R&D PMS should incorporate both qualitative and quantitative metrics. Quantitative measures provide a tangible benefit in that they allow for simple assessment of results. However, qualitative wisdom is necessary to understand the ever changing R&D process (Paparone & Crupi, 2006). Using qualitative metrics and understanding to supplement quantitative metric results is necessary for complexity associated with R&D assessment.

Themes associated with qualitative metrics include developing female scientists and effectiveness of peer review processes. Qualitative evaluation was noted to be necessary in the evaluation of holistic outcomes versus metric-by-metric evaluation. Quantitative themes include defined project time lines and budgets. For quantitative measures, the need to establish clear numerators and denominators for rating performance was noted. Interviews 1, 5, 6, and 7 identified this attribute. Literature supporting this characteristic included Brown and Gobeli (1992), Ojanen and Vuola (2003), and Paparone and Crupi (2006).

4.2.1.2 Clarifying. The second operational characteristic is clarifying. Clarifying refers to the system's ability to construct and articulate meaningful measures as well as monitor and address issues of uncertainty. The complexity of measurement associated with R&D requires that functions are in place to clarify expectations throughout the measurement life cycle. This applies to understanding of R&D projects as well as human understanding of expectations in an emergent R&D project environment.

Figure 10 describes the attributes identified during the open coding phase of the GTM that are associated with the operational characteristic *clarifying*.

Figure 10: Clarifying - Detailed layout diagram

Clarifying
• Interpreting • Long time horizon • Uncertainty

The attributes contributing to the operational characteristic *clarifying* are discussed in the following paragraphs.

Interpreting - Because ambiguity exists in R&D performance measurement, processes should be put in place to allow for clarification of expectations. Also, people conducting the work must be able to clarify their interpretation about what measurement results they actually must produce.

Themes include misunderstanding the intention of metric requirements, course correcting when there is disagreement about measurement requirements, misunderstanding measurement limitations, and unclear measurements resulting from unqualified metric developers. Interviews 1, 2, 5, 6, and 7 identified this attribute. Literature supporting this characteristic included Bremser and Barsky (2004), Pearson and Kerssens-van Drongelen (2000), and Wholey and Newcomer (1997).

Long Time Horizon – Return on investment for R&D projects is realized on a long time horizon relative to production and manufacturing. This, and typical R&D complexities, makes it difficult to clearly understand how well a project may be progressing. R&D metrics should be agile in consideration of sub-systems that lag behind or pull ahead of others during long R&D processes. When metric changes are made, they must be communicated clearly throughout the organization in a way that allows subsystems to understand their impacts on the new emergent vision and how the changes relate to the organization's long term outcomes.

Themes include accepting that multiyear measurements may be needed to generate meaningful data, communicating changes over time, adapting when interest wanes in a project over time, and not jumping to conclusions about data until sufficient time for measurement has elapsed (time scale in years were noted). Interviews 1, 3, and 4 identified this attribute. Literature supporting this characteristic included Bremser and Barsky (2004), Brown and Gobeli (1992), and Kerssens-van Dronglen and Cook (1997).

Uncertainty – The emergent nature of R&D requires that the organization embrace uncertainty, complexity, and risk during project life cycles. People may view the progress, value, or success of R&D projects differently. Processes that incorporate multiple perspectives and understandings, such as internal and external peer review, should be embraced to clarify a projects true progress towards desired outcomes. This requires time and resources be spent on developing an understanding of the R&D goals.

Themes include having to create programs before doing detailed analysis to understand if the ideas will work, estimating cost and schedules before when risks are unknown, getting performance measured against a guess, adjusting quality of research when cost and schedule measures can't be adjusted, understanding when measures are relevant or outdated, and focusing on smaller metrics when the larger picture lacks clarity. Interviews 2, 3, 5, and 6 identified this attribute. Literature supporting this characteristic included Metawie and Gilman (2005), Paparone and Crupi (2006), Smith and Clark (2006).

4.2.1.3 Evaluating. Evaluating refers to the methods used to compare and understand measurement results. Considerable investment goes into collecting measurements. If the PMS does not have a way to accurately understand the meaning behind the data, why make the investment? The measurement system must provide a means for evaluation and the data from the measures must be representative on the trajectory associated with what is being measured.

Figure 11 describes the attributes identified during the open coding phase of the GTM that are associated with the operational characteristic *evaluating*.

Figure 11: Evaluating - Detailed layout diagram

Evaluating
• Benchmarking • Metrics Assessment

The attributes contributing to the operational characteristic *evaluating* are discussed in the following paragraphs.

<u>*Benchmarking*</u> – Benchmarking refers to the way one system can be compared to another system or standard. Benchmarking in R&D is problematic because predicting outcomes associated with R&D innovation is difficult within the useful time scales for governance and management. Developing a system for comparison, often including SME peers, which can improve the understanding of context specific indicators, is essential.

Themes include building organizationally-specific outcomes from generalized categories, comparing the organization to competitors, maintaining a positive trajectory, sharing of information among peers, public rankings and classifications, the needs for normalization of ratings, and the need to standardize the evaluation of similar metrics among organizations. Interviews 1, 2, 3, 4, 5, 6, and 7 identified this attribute. Literature supporting this characteristic included Cocca and Alberti (2010), Kerssens-van Dronglen and Cook (1997), Najmi and Rigas (2005), and Szakonyi (1994b).

<u>*Metrics Assessment*</u> – For metrics to be useful, the results must add value to the organization once they are understood and used for decision making. Simply put, metrics must produce meaningful data. For example, measuring "lines of code written" without understanding the complexity of an algorithm or how it is tied to the organization's high level goals will not produce actionable results. This means that simple quantitative measures may be easy to assess but provide little value without qualitative indicators to add context to the measurements meaning.

Themes include building the measurement system to uncover problem areas, utilizing the knowledge of system experts to define how measures can be evaluated, using peer review to diagnose hidden problem areas, using a defined quantitative rating scale to define performance, utilize objective data when possible, and determine evaluation results based on outcomes. Interviews 1, 2, 5, 6, and 7 identified this attribute. Literature supporting this characteristic included Brown and Gobeli (1992), Metawie and Gilman (2005), and Van Aken et al. (2005).

4.2.1.4 Evolving. Evolving refers to system's ability to change in response to emergent conditions or understanding. An organization must have mechanisms in place to change in response to performance measurement results. In R&D, this may come from measurement results as well as information gained from expert critique. Organizations must have the ability to adapt their processes and measures in response to measurement results, feedback, funding changes, and dysfunctional behaviors.

Figure 12 describes the attributes identified during the open coding phase of the GTM that are associated with the operational characteristic *evolving*.

Figure 12: Evolving - Detailed layout diagram

Evolving
• Adaptability • Funding Uncertainty • Gaming • Incorporating Feedback

The attributes contributing to the operational characteristic *evolving* are discussed in the following paragraphs.

Adaptability – A viable PMS will provide a balance between stability and adaptation. It must provide a foundation and goal structure, based on the organization's mission, to establish criteria for measurement result expectations. However, the fuzziness associated with R&D outcomes and funding requires the system to be agile in the face of change. Overly adaptive systems risk making measurement results meaningless. This is because constant change can work contrary to the long term focus associated with R&D systems. Conversely, overly rigid systems can constrain R&D outcomes by excluding the impact of R&D discovery and forcing outcomes based on preconceived ideas.

Themes include metric changes based on multi-level discussions, establishing rigid high-level metrics while allowing detail level adaptation, allowing incremental change, reprioritizing tasks based on clarified metrics, managing unusual grants and funding, planning for multiple scenarios (funding/public perception), consideration of metric normalization, and managing the autonomy of different units being measured. Interviews 1, 2, 3, 4, 5, 6, and 7 identified this attribute. Literature supporting this characteristic included Beer (1979), Cocca and Alberti (2010), and Paparone and Crupi (2006).

Funding Uncertainty – Because the R&D function does not generate its own revenue, it must depend on other sources for funding. This may include government funding or money from production and manufacturing projects. Changes in yearly budgets, continuing resolutions, sequestration, and consumer markets require that the PMS to be agile enough to evolve and continue to drive improvement. Considering the long time horizon associated with R&D, creating a system that can survive these annual funding challenges is essential to R&D success.

Themes include trying to meet goals with less funding, prioritizing activities, limiting spending redundancy on competitive processes, diversifying funding sources, and issues surrounding performance-based contracts without a budget. Interviews 2, 3, 4, and 5 identified this attribute. Literature supporting this characteristic included Behn (2003), Brown and Gobeli (1992), and Paparone and Crupi (2006).

Gaming – Refers to peopling finding and using unintended ways to meet performance measurement goals to maximize their own benefits. Gaming undermines the entire measurement process and can cause problem ripples throughout the PMS. Therefore, processes must exist that address the issue of gaming at multiple levels of the organization.

Themes include falsifying project completion status, perpetual re-base lining, joining two systems together to give the illusion of better output, and presenting misrepresentative data to push through desired decision. Interviews 2, 4, and 7 identified this attribute. Literature supporting this characteristic included Metawie and Gilman (2005), Neely and Bourne (2000), and Paparone and Crupi (2006).

Incorporating Feedback – The primary goal of a PMS is to collect, discern and communicate the information required for the organization to improve. The organization must have a process for incorporating the feedback from performance measures. Without this feedback loop, the results gained from measurement cannot not be used to drive a structured improvement processes.

Themes include providing clear, honest assessment on how well goals are met, the benefits of informal communication channels, how feedback can help settle disagreements between innovators and management, using feedback to fix problems or solicit additional help and resources, and making decisions how to report externally. Interviews 1, 2, 3, 6, and 7 identified this attribute. Literature supporting this characteristic included Behn (2003), Neely and Bourne (2000), and Ojanen and Vuola (2003).

4.2.1.5 Humanizing. Humanizing refers to the human aspects and considerations associated with R&D PMS implementations. All performance measurement has a human component. This may manifest itself in the metric designs, specific expectations of performance, pressure to meet project milestones, articulation of requirements, and comprehension of complex measurement data.

Figure 13 describes the attributes identified during the open coding phase of the GTM that are associated with the operational characteristic *humanizing*.

Figure 13: Humanizing - Detailed layout diagram

Humanizing
• Coping with measurement expectations • Learning • Negotiating metrics

The attributes contributing to the operational characteristic *humanizing* are discussed in the following paragraphs.

Coping with Measurement Expectations – People working within a PMS will inevitably experience pressure associated with expectations. The PMS should develop clear, reachable goals and pathways for success for the people producing measurement data. When goals are unrealistic, targets slip and people stop realistic planning and instead become reactive (Kerssens-van Dronglen & Cook, 1997). In an attempt to fix issues they may pad schedule and cost estimates or attempt heroics to meet expectations.

Themes include disagreeing about R&D performance measurement outcome quality, creating clever ways to pad costs and performance goals to ensure the project has sufficient funds to get completed, accepting funding for a project when you know you can't accomplish it for the amount, and dealing with new demands when funding profiles won't change. Interviews 1, 2, and 5 identified this attribute. Literature supporting this characteristic included Kerssens-van Dronglen and Cook (1997), Paparone and Crupi (2006), and Waal and Counet (2009).

Learning – It is the people, not the measures, that must be able to gain insight from metric evaluation and interpret the results used to identify problems, emergent issues and cause and effect relations. This knowledge is then used to increase efficiency and drive the system towards improvement. The PMS must identify and engage the right people to make sense of metric results to make learning efficient and effective in R&D.

Themes include using data to improve business functions, determine what is needed to allow the organization to compete, re-evaluate expectations, increase overall reliability, and evaluate the effects of change over time. Interviews 3, 4, 6, and 7 identified this attribute. Literature supporting this characteristic included Behn (2003), Harty (1999), and Waal and Counet (2009).

Negotiating Metrics – The subjective nature of R&D means that people attempting to measure performance need to stay engaged with the experts immersed in the development. People developing measures need to communicate with R&D experts to update measures throughout a system's life cycle. Failing to do this can lead to measurements that don't fit the current context as supporting R&D methods evolve.

However, negotiated goals must ultimately stay aligned with stakeholder requirements.

Themes include working with metric developers to create measurable goals, allowing negotiation to produce better personal accountability, re-negotiating metrics based on funding changes, and accepting risk when negotiations fail. Interviews 1, 2, and 5 identified this attribute. Literature supporting this characteristic included Behn (2003), Bourne et al. (2002), and Kleingeld et al. (2004).

4.2.1.6 Improving. Improving refers to the system's ability to make positive changes base on measurement results and emergent conditions. Improvement processes should clearly identify the people charged with improving the system and be defined so that the organization can follow a structured improvement process. PMS changes should be implemented in suitable time frames so that the organization does not spend undue time and resources on inappropriate tasks or measurement.

Figure 14 describes the attributes identified during the open coding phase of the GTM that are associated with the operational characteristic *improving*.

Figure 14: Improving - Detailed layout diagram

Improving
• Improvement Ownership • Periodic Maintenance

The attributes contributing to the operational characteristic *improving* are discussed in the following paragraphs.

Improvement Ownership – Organizations must identify the people who are responsible for achieving the goals tracked by performance measurements. These key users must be made to understand their role and how it ties into organizational outcomes.

Themes include communicating expectations between people measuring and people being measured, allowing the people tasked with owning the improvement expectation to communicate how deficiencies can be fixed, and considering improvement owner feedback for tweaking metrics. Interviews 1, 2, 3, 4, 5, 6, and 7 identified this attribute. Literature supporting this characteristic included Cocca and Alberti (2010), Waal and Counet (2009), and Wholey and Newcomer (1997).

Periodic Maintenance – Organizations must use measurement results to inform and drive the iterative changes needed to have a continuously improving PMS. Results from performance measurement analysis must be distributed to the proper parts of the organization for the system to remain viable. A feedback loop is necessary to drive this process. Effort and money is wasted if a defined process doesn't exist to drive the periodic maintenance.

Themes include disconnects between high-level metric evaluation and worker level dissemination, change driven by peer pressure when feedback is public, predicting feedback by utilizing internal critiquing, issues associated with feedback lagging to far behind work practices, using measurement results to revise performance measurement and the system in general based on trends in measurement results. Interviews 1, 2, 3, 4, 5, and 7 identified this attribute. Literature supporting this characteristic included Bititci, Turner, and Begemann (2000), Medori and Steeple (2000), and Neely and Bourne (2000).

4.2.1.7 Incentivizing. Incentivizing refers to the way in which the system drives compliance with the PMS requirements. For the PMS to be viable, there must be a means by which all subsystems are compelled to align with organization's performance measurement needs. Internally, this can be done though financial motivation, new positions, fears of reprisal, or positive feedback for desirable behavior. However, the R&D function may also need to influence their funders. This requires the PMS to develop a refined process that generates effective presentation of performance results.

Figure 15 describes the attributes identified during the open coding phase of the GTM that are associated with the operational characteristic *incentivizing*.

Figure 15: Incentivizing - Detailed layout diagram

Incentivizing
• Accountability • Incentivization • Showcasing

The attributes contributing to the operational characteristic *incentivizing* are discussed in the following paragraphs.

Accountability – An accountability process must be built into the PMS to account for the human elements in the system. Its purpose is to address elements of the system that are failing to achieve their performance goals in spite of positive incentives.

Themes include established reporting structures, informal evaluations, formal evaluation, changing managers based on performance, making managers produce more frequent reports on smaller objectives for bad performance, lack of mechanisms to push beyond goals, holding people to promised outcomes, being accountable to the public as an organization and defining what people and systems must be accountable for. Interviews 1, 2, and 3 identified this attribute. Literature supporting this characteristic included Metawie and Gilman (2005), Neely et al. (2000), and Wholey and Newcomer

(1997).

<u>*Incentivization*</u> – Incentives must be tied to performance metrics to effectively influence system and employee behavior. These incentives must be designed such that they motivate the people in the systems to achieve the organization's desired outcomes. This process often involves subjective evaluation to understand performance and to decide on effective motivational factors.

Themes include increasing personal or organizational value, increasing contractual terms, earning allocations of awards, and more favorable positions or responsibilities. Interviews 1, 5, and 6 identified this attribute. Literature supporting this characteristic included Behn (2003), Hester et al. (2010), and Metawie and Gilman (2005).

<u>*Showcasing*</u> – Showcasing refers to the way in which an organization presents their success such that it generates stakeholder interest. Successful showcasing, in turn, often leads to additional or continued funding.

Themes include working with stakeholders to develop attainable outcomes, presenting current status and soliciting feedback, tying public attention to research interests, determining what the stakeholders find interesting, and creating impactful presentations. Interviews 1, 3, 4, and 7 identified this attribute. Literature supporting this characteristic included Behn (2003), Brown and Gobeli (1992), Northcutt and Taulapapa (2012), and Wholey and Newcomer (1997).

4.2.1.8 Projecting. Projecting refers to the organization's ability to project its identity throughout the PMS. Organizations need to select and define their performance measures to support the operating issues and desired outcomes associated with the system's mission. R&D organizations must consider measurement selection carefully in this respect as a result of pressures associated stakeholders and funding agencies. While stakeholder considerations must be taken into account, their focus may be short term and misaligned with the R&D function and the organization's mission

Figure 16 describes the attributes identified during the open coding phase of the GTM that are associated with the operational characteristic *projecting*.

Figure 16: Projecting - Detailed layout diagram

Projecting
• Innovational Requirements • Mission Alignment • Steering

The attributes contributing to the operational characteristic *projecting* are discussed in the following paragraphs.

Innovational Requirements – Innovation is a requirement in an R&D context. The purpose of the R&D function is to develop new products, ideas, or solutions that may benefit an organization over an extended time horizon. Innovation plays a central role in the abilities of the R&D unit to produce expected and meaningful outcomes.

Themes include using external reviews to determine prioritization of idea development, how funding limits innovation implementation, how government backing may mean more stringent requirements on unique ideas, the subjective nature of idea assessment, and the need have a function to bridge from conceptual ideas to practical implementation. Interviews 3, 5, and 6 identified this attribute. Literature supporting this characteristic included Fitzgerald et al. (1991), Kaplan (2008), Kerssens-van Drongelen and Bilderbeck (1999), Neely et al. (2000), and Tangen (2005).

Mission Alignment - A PMS should produce metrics that are based on and support the organization's mission. When implemented at multiple hierarchical levels in an organization, the metrics should align with and support each other to produce the mission's intended outcomes.

Themes include establishing a defined scope that supports the organization's mission including specific objectives, operational, business and leadership goals, engaging your primary stakeholder in deciding the organization's mission, the need for formalized systems that tie metrics to mission, and the need for senior leadership review of implementation of metrics to assure their alignment with mission. Interviews 1, 2, 6, and 7 identified this attribute. Literature supporting this characteristic included Kaplan and Norton (2007), Metawie and Gilman (2005), and Neely et al. (2005).

Steering – Steering is the communication and projection of the vision, rules, and principles needed to guide a system towards desired outcomes and convey the organization's strategy throughout the system. People that are responsible for organizational success must understand, accept, and be engaged with the performance measurement process. Leadership must communicate how metrics add value and how their contributions, both optimally and sub-optimally, affect mission outcomes.

Themes include making decisions on how to address significant funding issues, creating cohesion among multiple business units, establishing and communicating the organization's long term vision, and developing new strategic plans. Interviews 1, 3, 4, 5, 6, and 7 identified this attribute. Literature supporting this characteristic included Cocca and Alberti (2010), Kaplan and Norton (2007), and Neely et al. (2000).

4.2.1.9 Servicing. Servicing refers to organization's abilities to meet the needs of their stakeholders so as to maintain the organization's existence. Stakeholders have specific expectations for the R&D function and they often face mandates from the government. These mandates may result from government regulations such as innovational or safety requirements, or in private R&D in areas such as of drug testing and product safety.

Figure 17 describes the attributes identified during the open coding phase of the GTM that are associated with the operational characteristic *servicing*.

Figure 17: Servicing - Detailed layout diagram

Servicing
• Ensuring Continued Funding • Incorporating Stakeholder Mandates

The attributes contributing to the operational characteristic *servicing* are discussed in the following paragraphs.

Ensuring Continued Funding – The R&D function typically does not generate revenue directly (there are exceptions such as contracted R&D companies). Performance measures must exist which can highlight the functions ability to operate effectively. The measurement results can then be used to solicit funding.

Themes include completing project goals on time and on budget, identifying measures that the funder will find useful, and work for others (matrixed time to other organizations, purchased released time etc.). Interviews 1, 2, 3, and 4 identified this attribute. Literature supporting this characteristic included Boland and Fowler (2000), Kerssens-van Dronglen and Cook (1997), and Szakonyi (1994b).

Incorporating Stakeholder Mandates – Stakeholders for R&D organizations, both public and private, often include government and public influences. Stakeholder requirements may be imposed on R&D processes and incorporated into R&D metrics. Performance measurement system designs must consider how they can incorporate emergent stakeholder mandates while maintaining the organization's identity.

Themes include incorporating OSHA regulations, FDA requirements, publicity through news channels, and diversity requirements. Dysfunctional behaviors were also identified such as "box checking", creating a paper illusion of work being completed, and "studying to the test", diverting or combining resources to produce a favorable result without actually performing the intended work. Interviews 3, 5, and 7 identified this attribute. Literature supporting this characteristic included Behn (2003), Metawie and Gilman (2005), Neely et al. (2002), and Tangen (2005).

4.2.1.10 Sharing. Sharing refers to the transparency of performance measurement information and results. Organizations need to be able to share performance data internally to ensure that progress is made towards the organization's mission, that different subsystems are appropriately integrated and working efficiently, and that subsystem abilities are understood and calibrated against others within the organization. R&D organizations are also expected to share information externally. This is required in public organizations who must assure government funders that their work meets federal expectations and in private industry to assure government that products safety requirements are achieved. Peer review serves as a means to make these checks by using SMEs to probe the soundness of performance claims. However, there may be resistance to transparency as this may cause organizational members to feel threatened by the exposure of information (Waal & Counet, 2009).

Figure 18 describes the attributes identified during the open coding phase of the GTM that are associated with the operational characteristic *sharing*.

Figure 18: Sharing - Detailed layout diagram

Sharing
• External Transparency • Internal Transparency • Peer Review

The attributes contributing to the operational characteristic *sharing* are discussed in the following paragraphs.

External Transparency – An organization must provide information that stakeholders can use to determine how well the organization is meeting their needs. This information should be easily accessible, up-to-date, provide all required information to assess the true state of the organization, and be presented in an understandable way.

Themes include pressure to only deliver desirable results, setting useful reporting intervals, a correlation between review level and transparency level (more transparency means more need for external review), and reporting in a way that can be used to benchmark against other organizations. Interviews 1, 2, 3, 5, 6, and 7 identified this attribute. Literature supporting this characteristic included Northcutt and Taulapapa (2012), Waal and Counet (2009), and Wholey and Newcomer (1997).

Internal Transparency – Transparency within an organization refers to the sharing of information. For the information to be transparent, it cannot be manipulated to exhibit results from a particular perspective. The feedback functions should also exhibit transparency so that the organization understands its strengths and weaknesses.

Themes include formal and informal meetings, internal reviews, reports, web-based access, and the use of peer pressure can be used as a motivator. Interviews 1, 2, 3, 4, 5, and 6 identified this attribute. Literature supporting this characteristic included Paranjape et al. (2006), Waal and Counet (2009), and Wholey and Newcomer (1997).

Peer Review –The complex and emergent nature of R&D makes peer review a useful tool. The R&D context is often fuzzy and people's thinking can become narrowed to the task at hand. Peer reviews add different perspectives and force people within a closed system to understand their performance in the larger context. The most useful qualitative assessments should be expected from independent outside reviewers conducting formal reviews.

Themes include the value of self assessment while preparing for reviews, backing up issues identified by less senior staff, providing additional expertise, setting up review frequencies, that peer review clarifies subjective issues, and how peer review identifies issues that would not be uncovered by internal staff. Interviews 2, 3, 5, and 6 identified this attribute. Literature supporting this characteristic included Kerssens-van Dronglen and Cook (1997), Metawie and Gilman (2005), and Ojanen and Vuola (2003).

4.2.1.11 Supporting. Supporting refers to the organizational tools and management that must be present for the PMS to function. Supporting includes both infrastructure to support the metric data and managerial support to back the measurement process itself. Depending on the size of the organization, these functions may take the form of organizational subsystems or exist within the job function of individuals. An information technology system, used to monitor and analyze measurement data, is a staple of all well developed modern PMSs. The system must also provide a means for dissemination of measurement analysis results.

Figure 19 describes the attributes identified during the open coding phase of the GTM that are associated with the operational characteristic *supporting*.

Figure 19: Supporting - Detailed layout diagram

Supporting
• Information Technology • Organizational Support

The attributes contributing to the operational characteristic *supporting* are discussed in the following paragraphs.

Information Technology – Today's organizations need a well developed IT infrastructure to manage, track, evaluate, rate, and disseminate performance measurement information. The system should be distributed across the organization such that metric information for relevant sub-systems is fully integrated. A feedback loop is also required to maintain homeostasis by providing required information for updating metrics and/or re-allocate resources.

Themes include establishing authenticated access to different information, automated email updates, automated reports, integration of software tools to manage and track information, and the ability to collectively analyze the impact of multiple sub-systems on system outcomes, databases storage of metric information, defined system for broadcasting information through meetings and reports, defining expectations (what is due when), and using pooled data to gauge system reliability. Interviews 1, 2, 4, 5, 6, and 7 identified this attribute. Literature supporting this characteristic included Bititci et al. (2000), Bourne et al. (2002), and Waal and Counet (2009).

Organizational Support – Even the best systems will fail if they do not have sufficient organizational support. Failures may result from lack of support from upper management, including funding and resources, as well as resistance to change from lower organizational levels. Organizational governance must present a clear mission and vision, clarify organizational outcomes, and actively address disagreements among multiple organizational levels to support the desired organizational outcomes.

Themes includes the need to measure issues important to the organization's mission, presence and availability of governing entities, alignment of mission to performance measures, and having sufficient resources and departments to provide avenues to success for the things being measured. Interviews 4, 5, 6, and 7 identified this attribute. Literature supporting this characteristic included Kaplan and Norton (2007), Neely et al. (2002), and Waal and Counet (2009).

4.2.1.12 Tailoring. Tailoring refers to the way in which an organization creates their contextually specific PMS. The organization must consider the contextual appropriateness of the measures, the means by which metrics are selected, and the skill set of the people who are developing metrics and analyzing results.

Figure 20 describes the attributes identified during the open coding phase of the GTM that are associated with the operational characteristic *tailoring*.

Figure 20: Tailoring - Detailed layout diagram

Tailoring
• Contextual Alignment • R&D Metric Development • Right Skill Sets

The attributes contributing to the operational characteristic *tailoring* are discussed in the following paragraphs.

<u>Contextual Alignment</u> – Contextual alignment refers to the way performance measures are applied in specific contexts. Organizational metrics should be developed to be context specific; however, emergent conditions can require additional consideration outside the boundaries of normal operation of the PMS.

Themes include developing evaluation techniques over long time horizons, seeking expert help in the development of appropriate measures, maintaining reliable measures, and picking suitable measures for context specific situations. Interviews 1, 3, 4, 6, and 7 identified this attribute. Literature supporting this characteristic included Behn (2003), Cocca and Alberti (2010), Hester and Meyers (2011), Kaplan (2008), Kleingeld et al. (2004); Neely et al. (2002), Ojanen and Vuola (2003), and Scott (2005).

<u>R&D Metric Development</u> – Mature R&D metrics are built using a defined process that ensures the metrics continuously support long term mission outcomes. The system should utilize MOPs and MOEs to understand how the measurement objectives "relate to organizational improvement, purposes, and operational context" (Hester & Meyers, 2012, p. 6). Over reliance on qualitative data may lead to un-actionable metric results while over reliance on quantitative data can fail to accurately represent the complexity of R&D and lead to the organization producing better numbers but not successful outcomes.

Themes include measures that address technical requirements, business processes and leadership quality, problems with tracking project cost goals but not technical performance, creating contextually appropriate measures, removing ineffective measures, improving metrics by focusing on outcomes related to research goals, focusing on the few critical parameters required for a particular project, providing metric "knobs" that can be negotiated, and providing measurement frameworks that can be used for contextually appropriate metric selection. Interviews 1, 2, 3, 4, 5, 6, and 7 identified this attribute. Literature supporting this characteristic included Hester and Meyers (2012), Meyers and Hester (2011), Smith and Clark (2006), Sproles (2002), and Stevens (1979).

Right Skill Sets – Organizations need to have people with the right skills to accomplish the R&D goals and to establish relevant and effective metrics. This requires that the organization compile and retain people with sufficient experience, education, and expertise to achieve the desired R&D outcomes.

Themes include having people that can push back on inappropriate metrics, having people that can establish realistic R&D goals, relying on experienced people who have worked on similar R&D projects, and making sure system owners have the ability to understand how the metrics they are responsible for fit into the high level R&D outcomes. Interviews 1, 2, 3, and 6 identified this attribute. Literature supporting this characteristic included Bourne et al. (2002), Brown and Gobeli (1992), Szakonyi (1994a), and Waal and Counet (2009).

4.2.2 Detailed characteristics summary. This section provided a detailed description of the operational characteristics necessary for an effective R&D PMS at the enterprise level. The associated attributes for each characteristic were then presented and defined. Supporting themes from the GTM were then given to describe further context to the attributes' meaning. At least three references from GTM interviews and three references from literature, detailed in the discussion, were required for each attribute to further validate the strength and significance of the research findings. These operational characteristics, grounded in empirical data and supported by literature, provide a significant contribution to the body of knowledge associated with R&D performance measurement systems. These results answer the first research question:

- What operational characteristics are necessary for an effective R&D performance measurement system at the enterprise level?

With this foundation established, and the first research question closed, the discussion can now move on to the next phase: alignment of operational characteristics with systems theory concepts.

4.3 SYSTEMS ALIGNMENT

As discussed in Chapter 3, systems theory provides a methodological framework suitable for systemic thinking about organizational issues. The axioms, detailed in the same chapter, provide a suitable foundation for systems theory and thinking for use in this research study. These axioms have been used to provide the "lens" through which one can look at the operational characteristics and their associated attributes as they occur in the real world. The following section details the way in which the system axioms have been used to provide systemic consideration, beyond the GTM, to the operational characteristics. It should be thought of as a verification of the linkage of systems "coverage" with the operational characteristics. This alignment answers the second research question:

- What systems theory concepts apply to the assessment of performance measurement systems in an R&D environment?

Table 12 presents an overview of the alignment of systems axioms to operational characteristics. It is not meant to be used as a judgment of the "goodness of fit" for the alignment. It is meant to identify if axiomatic systems' perspectives may have been missed during the open and axial coding. The details of the alignment between the systems axioms and operational characteristics are provided in this section.

Table 12: Systems Alignment to R&D Operational Characteristics

		Systems Axioms						
		Centrality	**Contextual**	**Goal**	**Operational**	**Viability**	**Design**	**Informational**
Operational Characteristics	**Balancing**						•	
	Clarifying		•					
	Evaluating			•	•	•		•
	Evolving	•		•				
	Humanizing	•						
	Improving			•				
	Incentivizing						•	
	Projecting	•				•		
	Servicing		•					
	Sharing		•					•
	Supporting		•					
	Tailoring				•			

Each axiom and its associated propositions are presented in this section. These are followed by a brief description of the alignment between the propositions and attributes of each operational characteristic shown in the table. The descriptions do not constitute an alignment of each attribute and proposition. Rather, they detail a criterion that argues for the legitimacy of systems coverage resulting from the operational characteristic identification from the GTM.

Table 12, as well as the following analysis, has been ordered to follow the axiom definitions defined in Chapter 3 (Adams et al., 2014). Although these axioms are not inclusive of all systems principles, they represent a "common practical perspective for systems theory" (Adams et al., 2014, p. 1). There are many methodologies and approaches that could be used to establish a systems basis for this dissertation's research findings. The axioms and their associated principles were chosen because they provide a rigorous, balanced, and concise method to establish a systems basis from which this dissertation's grounded theory findings can be compared. As with the previous section, the ordering of axioms, operational characteristics, or attributes does not imply any ranking. Throughout this section, each axiom alignment will list the axiom's propositions followed by the explored operational characteristics. Details of the alignment will be described at the attribute and proposition level. Figure 21 describes the ordering.

Figure 21: Systems axioms alignment format

- Operational Characteristic
    - Attribute 1
        - Axiom Proponent – (Alignment description)
    - Attribute 2
        - Axiom Proponent – (Alignment description)
    - Attribute n
        - Axiom Proponent – (Alignment description)

A diagram of the detailed structural breakdown of each axiom alignment is described in Appendix D.

4.3.1 The Centrality axiom alignment. The first axiom alignment discussed will involve the centrality axiom. The centrality axiom states that central to all systems are two pairs of propositions; emergence and hierarchy, and communication and control. The primary principles for the centrality axiom are communication, control, emergence, and hierarchy (Adams et al. 2014). The attributes associated with the operational characteristics *evolving, humanizing and projecting* were found to align to the systems centrality axiom. Figure 22 provides the elements included in the alignment process. A detailed description for the alignment and a brief example for each is provided below:

Figure 22: *Centrality* axiom alignment to operational characteristics

Evolving	Humanizing	Projecting
• Incorporating Feedback • Adaptability • Funding Uncertainty • Gaming	• Coping with measurement expectations • Negotiating Metrics • Learning	• Innovational Requirements • Steering • Mission Alignment

Evolving

The following details alignment of the attributes associated with the *evolving* characteristics with the principles associated with the *centrality* axiom.

- Incorporating Feedback
    - Communication – Performance measurement feedback, in its simplest case, provides positive or negative information associated with the measurement results.
    - Control – Information gained from the measurement process must be used to improve the organization while continuing to support the organization's mission and retain its identity.
- Adaptability
    - Control - A viable PMS will provide a balance between stability and adaptation.
- Funding Uncertainty
    - Control – The long time horizon associated with R&D require the PMS to adjust to annual funding challenges while maintaining the organization's identity.
    - Emergence – Funding constraints will lead to emergent strategies used to meet the organization's outcome expectations. These strategies will not be known until funding is changed and the organization understands the current state of its R&D development.

- Gaming
    - Hierarchy – Performance measures are built to drive organizational improvements. However, sub-systems may find emergent ways to meet measurement requirements. These ways that may not align, or may even conflict, with the organization's intentions.

Humanizing

The following details alignment of the attributes associated with the *Humanizing* characteristics with the principles associated with the *Centrality* axiom.

- Coping with measurement expectations
    - Hierarchy – The individuals working to ensure that performance measurement expectations are reached are a part of the organizational hierarchy. As the expectations are introduced to different organizational levels, different interpretations, understanding, and engagement will affect the individual results and the system as whole.
- Negotiating Metrics
    - Control – Organizations must be able to work with system experts and stakeholders to create measures that maintain the system's identity.
- Learning
    - Control – The learning process associated with performance measurement provides the information needed to inform system changes to retain performance standards.

- Emergence – Learning will inform various attributes of a system's parts. As these parts adapt to make individual improvements, the overall system can be expected to exhibit new properties.

Projecting

The following details alignment of the attributes associated with the *projecting* characteristics with the principles associated with the *centrality* axiom.

- Innovational Requirements
  - Control – The R&D function must meet innovational requirements, often imposed on it by stakeholders. As the R&D function incorporates these requirements, they must ensure that they maintain their identity by linking innovational metrics to the R&D long term mission.
- Steering
  - Hierarchy – An R&D governance function must exist to ensure the subsystems of the organization continue to support the R&D mission in spite of the emergent nature of R&D work.
- Mission Requirements
  - Emergence – R&D innovation leads to emergent discoveries. As new learning occurs in the R&D process, mission requirements must be evaluated so that the processes, requirements, or the mission itself can be improved.

4.3.2 The contextual axiom alignment. The second axiom alignment discussion will center on the contextual axiom. The contextual axiom states that *system meaning is informed by the circumstances and factors that surround the system.* The contextual axiom's principles are those which give meaning to the system by providing guidance that enable an investigator to understand the set of external circumstances or factors that enable or constrain a particular system. The primary principles associated with the contextual axiom are complementarity, darkness, and holism (Adams et al. 2014). The attributes associated with the operational characteristics *clarifying, servicing, sharing, and supporting* were found to align to the *contextual* axiom. Figure 23 provides the elements included in the alignment process. Again, a detailed description for each follows:

Figure 23: *Contextual* axiom alignment to operational characteristics

Clarifying	Servicing	Sharing	Supporting
• Uncertainty • Interpreting • Long Time horizon	• Incorporating Stakeholder Mandates • Ensuring Continued Funding	• Internal Transparency • External Transparency • Peer Review	• Information Technology • Dissemination / Feedback

<u>*Clarifying*</u>

The following details alignment of the attributes associated with the *clarifying* characteristics with the principles associated with the *contextual* axiom.

- Uncertainty
  - Complementarity – There may be different understanding of the intentions associated with metrics between the metric designer and the people who are in charge of reaching metric milestones.

- Interpreting
  - Complementarity – Different perspectives and understandings require the need for clarification of metrics. These different perspectives may offer completely different views of how well expectations have been met.
- Long Time Horizon
  - Darkness – When subsystems are given expectations, the will inevitably work to achieve them, even at the expense of other subsystems. The long time horizons associated with R&D require the PMS to provide appropriate measures to manage short term project impacts on the long term organization's mission.

Servicing

The following details alignment of the attributes associated with the *servicing* characteristics with the principles associated with the *contextual* axiom.

- Incorporating Stakeholder Mandates
  - Complementarity – There may be different perspectives about what metrics are important between metrics designers and stakeholders.
  - Darkness – An organization will not be able to anticipate all stakeholder requirements. Without stakeholder feedback, an organization may create self-serving, easily reached metrics.

- Ensuring Continued Funding
    - Holism – The R&D function is often dependent on funding from external agencies or departments. Without the external funders, the R&D organization cannot survive on its own. Staying engaged with the stakeholders that provide this funding is essential to survival of the R&D function.

Sharing

The following details alignment of the attributes associated with the *sharing* characteristics with the principles associated with the *contextual* axiom.

- Internal Transparency
    - Darkness – Subsystems within an organization must share information to understand their effects on each other and the system as a whole.
- External Transparency
    - Darkness – An organization must share information with their stakeholders. This provides the opportunity for stakeholders to understand the organization's current status and to feedback deltas between the current status and expectations.
- Peer Review
    - Complementarity – Peer review is used to provide a different perspective of a system that can be used to either affirm current methods or inform system changes.

Supporting

The following details alignment of the attributes associated with the *supporting* characteristics with the principles associated with the *contextual* axiom.

- Information Technology
  - Holism – The IT infrastructure supports various areas of the organization. However, it is essential to the PMS in that it captures, analyzes, and disseminates data so that the organization can promote informed real time improvement and change.
- Organizational Support
  - Holism – Without the support of upper management, the PMS is destined to fail. A PMS needs support from all levels of the organization to succeed.

4.3.3 The goal axiom alignment. The third axiom alignment discussion involves the goal axiom. The goal axiom states that *systems achieve specific goals through purposeful behavior using pathways and means*. The goal axiom's principles address the pathways and means for implementing systems that are capable of achieving a specific purpose. The primary principles associated with the contextual axiom are equifinality, multifinality, purposive behavior, satisficing, and viability (Adams et al. 2014). The attributes associated with the operational characteristics *evaluating, evolving, and improving* were found to align to the *goal* axiom. Figure 24 provides the elements included in the alignment process and, again, a detailed description for each follows:

Figure 24: *Goal* axiom alignment to operational characteristics

Evaluating	Evolving	Improving
• Benchmarking • Metric Assessment	• Incorporating Feedback • Adaptability • Funding Uncertainty • Gaming	• Periodic Maintenance • Improvement Owners

Evaluating

The following details alignment of the attributes associated with the *evaluating* characteristics with the principles associated with the *goal* axiom.

- Benchmarking
  - Purposive Behavior -- Benchmarking provides organizations a means to compare their performance against each other. This allows multiple organizations to understand how well they are meeting shared goals versus their competitors.
  - Viability – While the goal of benchmarking is to be able to compare, the organization must be careful to maintain contextually appropriate measures. When done blindly, generic implementation can result in excessive, redundant, or flawed measures.
- Metric Assessment
  - Equifinality – Metric results must provide the information needed for the system to understand how to move to a steady state or a steady trajectory of improvement.

  - Multifinality – Without clear direction, systems may execute the same tasks very differently. Evaluation of metric data will provide data for the PMS to increase system reliability.
  - Satisficing – When evaluating metrics organizations must balance resource investment and their return on investment. At some point, metric achievement may become adequate for the requirement and will no longer warrant the additional resources needed to make further incremental improvements.

Evolving

The following details alignment of the attributes associated with the *evolving* characteristics with the principles associated with the *goal* axiom.

- Incorporating Feedback
  - Multifinality – With effective communication between developers, organizational leadership, and stakeholders, very different end states are possible with R&D outputs. Constant communication, solicitation of feedback, and course corrections can identify problems that lead to these undesirable end states.
- Adaptability
  - Viability - Balance must be maintained between system stability and adaptation. If the PMS is consistently adapting, metrics will never be meaningful over the long time horizons associated with R&D.

- Funding Uncertainty
    - Satisficing – Because R&D budgets are often based on government funding or departmental success outside of the R&D function, financial uncertainty is a common theme. Tighter budgets may force organizations to accept poorer performance in terms of schedule or outputs.
- Gaming
    - Multifinality – Gaming will cause the system to generate meaningless metric results which, in turn, will lead to poor decision making and/or resource allocation. This will undermine R&D outcomes in terms of product quality and organizational efficiency.
    - Purposive Behavior – Organizations should expect that individuals will look for the simplest paths available to attain their goals. Organizational monitoring functions should be in place to identify dysfunctional behaviors.

Improving

The following details alignment of the attributes associated with the *improving* characteristics with the principles associated with the *goal* axiom.

- Periodic Maintenance
    - Multifinality – As new conditions internal or external to the system emerge, the PMS may detect differences in metric results or cause differences in metric processes being measured. This may come from issues such as excessive measurements over long time periods or people trying to meet established milestones with fewer resources.

  - Satisficing – Established metrics may need to be improved periodically to drive intended behaviors. However, the output requirements must be weighed when requiring changes. Striving for perfection in areas that do not require it can lead to cost overruns and lost time and resources.
- Improvement Owners
  - Purposive Behavior – Improvement owners provides the organization the ability to identify engaged, accountable individuals that will help the organization reach its mission goals. In turn, the improvement owners expect the resources and organizational backing necessary to make the goals attainable.
  - Viability – While a goal of the PMS is to establish metrics that will be representative of the state of a system, engagement of the individuals that own the responsibility of reaching performance goals is essential. This requires the system to have knobs available to specify measures in ways that allow the improvement owners to maintain some autonomy over their responsibilities.

4.3.4 The operational axiom alignment. The fourth axiom alignment centers on the operational axiom. The operational axiom states that *systems must be addressed in situ, where the system is exhibiting purposeful behavior*. The operational principles provide guidance to those that must address the system in situ, where the system is functioning to produce behavior and performance. The primary principles associated with the operational axiom are dynamic equilibrium, homeorhesis, homeostasis, redundancy, relaxation time, self organization, and sub-optimization (Adams et al. 2014). The attributes associated with the operational characteristics *evaluating, tailoring, and supporting* were found to align to the *operational* axiom. Figure 25 provides the elements included in the alignment process and, again, a detailed description for each follows:

Figure 25: *Operational* axiom alignment to operational characteristics

Evaluating	Tailoring	Supporting
• Benchmarking • Metric Assessment	• Contextual Alignment • Right Skill Sets • R&D Metric Development	• Information Technology • Organizational Support

<u>*Evaluating*</u>

The following details alignment of the attributes associated with the *evaluating* characteristics with the principles associated with the *operational* axiom.

- Benchmarking
    - Homeostasis – Using benchmarks allows the organization to compare itself to its competitors and thus understand where performance is exceptional, average, or lacking. This information can be used to allow stability in methods and expectations once acceptable results are attained based on the benchmarks.

- Metric Assessment
  - Redundancy – Using multiple methods to analyze performance measurement results can increase the reliability of measurement findings through increased statistics and addressing multiple perspectives.

Tailoring

The following details alignment of the attributes associated with the *tailoring* characteristics with the principles associated with the *operational* axiom.

- Contextual Alignment
  - Homeorhesis – The PMS must include measures that are appropriate over the long time horizons associated with R&D. Short term measures will aim the organizational trajectory at a short term focus.
  - Redundancy – Providing metrics that can be used as benchmarks as well as others that are aligned specifically to the organizational context can provide improved reliability of the system and a better understanding of attained and attainable performance. An example of this would be measuring a mechanical device's typical reliability, which would provide benchmark information, and also measuring the device's reliability in high magnetic fields, which would be a contextual requirement.
- Right Skill Sets
  - Homeostasis – Individuals in R&D organizations must have the right skills to make the difficult decisions associated with innovational requirements. Lack of skill could result in the organization failing to effectively regulate

itself based on changes driven by bad metrics or interpretation of metric results.

- R&D Metric Development
    - Redundancy – Sufficient measures should be put in place to allow the PMS to increase statistics and provide greater reliability concerning a measurement area. This redundancy may include quantitative measures supplemented with qualitative measures.
    - Sub-optimization – Metrics should be defined to allow subsystems to have reachable milestones. However, if left unmonitored, some subsystems may seek to beat estimates for production or schedule at the expense of other parts of the organization.

Supporting

The following details alignment of the attributes associated with the *supporting* characteristics with the principles associated with the *operational* axiom.

- Information Technology
    - Redundancy – An IT system may be able to collect the same information from multiple groups, divisions, or individuals. It may also be able to distribute information using multiple methods.
    - Homeostasis – The IT system provides the tools to retrieve, analyze, and distribute measurement information. This provides the means for the system to regulate its internal environment.

- Organizational Support
  - Dynamic Equilibrium – Organizational support from both management and support staff is required to maintain a working PMS. If there is a lack of management support, supporting staff will often not buy into the PMS. If the support staff resists the PMS requirements, management will have to add additional resources to control behavior.
  - Homeorhesis – If the management fails to support the measurement system, the system will revert back to business as usual.
  - Homeostasis – If appropriate resources and organizational support are allocated to the PMS, it will remain viable. This includes the ability of the organization to re-allocated budget as necessary to handle emergent conditions associated with metric analysis and results.
  - Redundancy – Mature organizations will use multiple methods to convey performance measurement information. For example, organizations may use meetings, emails, reports, and one-on-one feedback to convey a specific message.
  - Self Organization – As the organization becomes more familiar with a stable PMS, the culture of the organization will change to accept metric requirements and expectations.

4.3.5 The viability axiom alignment. The fifth axiom alignment involves the viability axiom. The viability axiom states that *key parameters in a system must be controlled to ensure continued existence*. The viability principles address how to design a system so that changes in the operational environment may be detected and affected to ensure continued existence. The primary principles associated with the viability axiom are circular causality, feedback, recursion, requisite hierarchy, requisite and variety (Adams et al., 2014). The attributes associated with the operational characteristics *projecting and evolving* were found to align to the *viability* axiom. Figure 26 provides the elements included in the alignment process and, again, a detailed description for each follows:

Figure 26: *Viability* axiom alignment to operational characteristics

Projecting	Evolving
• Innovational Requirements • Steering • Mission Alignment	• Incorporating Feedback • Adaptability • Funding Uncertainty • Gaming

Projecting

The following details alignment of the attributes associated with the *projecting* characteristics with the principles associated with the *viability* axiom.

- Innovational Requirements
    - Circular Causality – If the organization defines an innovational goal, then the system will work to meet the requirements of the goal. This may be at the expense of other required organizational needs.
    - Requisite Hierarchy – The more uncertainty there is in the organization's innovational requirements, the more management is required in directing the system towards the innovational goals.

- Steering
  - Feedback – Measurement information should be used to evaluate if the organization has adopted the culture desired as a result of steering.
  - Recursion – Steering is the communication and projection of the vision, rules, and principles needed to guide a system towards desired outcomes and convey the organization's strategy throughout the system. This requires each level of the organization to communicate the same message to each successive organizational level.
  - Requisite Hierarchy – The emergent nature of R&D requires strong regulatory abilities within the organization. The organization must have sufficient hierarchy to steer towards consistent mission outcomes.
- Mission Alignment
  - Requisite Variety – If an organization expects to align its culture with the mission, it must provide the mechanisms to communicate the mission and incentivize alignment of the people within the organization.

<u>Evolving</u>

The following details alignment of the attributes associated with the *evolving* characteristics with the principles associated with the *viability* axiom.

- Incorporating Feedback
  - Feedback – Feedback must be incorporated from metric results and stakeholders to direct the system towards its goals.

  - Recursion – Once feedback is accepted at the governance level of the organization, it will need to be disseminated recursively throughout the subsystems of the organization.
- Adaptability
  - Circular Causality – System adaptations are made to drive improvements in the system. However, these changes can also manifest themselves in unintended ways.
  - Recursion – As the organization changes to deal with funding issues and new requirements, sub-systems will also be required to adapt their processes and abilities.
  - Requisite Variety – The evolving nature of R&D require the organization to provide sufficient control mechanisms to manage emergent conditions.
- Funding Uncertainty
  - Circular Causality – Dealing with funding uncertainty requires the organization to dedicate additional time and resources to address multiple schedule prospects and process decisions. It cannot be assumed that a direct reduction or addition to funding will produce scalable results.
- Gaming
  - Requisite Variety – As new conditions emerge, systems will seek to find new paths of least resistance to enable reportable success. To prevent gaming, the organization must have sufficient variety to recognize the emergent issues, find a means to correct it, and monitor future behavior.

4.3.6 The design axiom alignment. The sixth systems axiom alignment involves the design axiom. The design axiom states that the system design is a purposeful imbalance of resources and relationships. The design principles provide guidance on how a system is planned, instantiated, and evolved in a purposive manner. The primary principles associated with the design axiom include minimum critical specification, Pareto, requisite parsimony, and requisite saliency (Adams et al. 2014). The attributes associated with the operational characteristics *balancing and incentivizing* were found to align to the *design* axiom. Figure 27 provides the elements included in the alignment process. The detailed description for each element follows:

Figure 27: *Design* axiom alignment to operational characteristics

Balancing	Incentivizing
• Multiple Perspectives • Investment Time and Resources • Qualitative and Quantitative Measures	• Incentivization • Accountability • Showcasing

<u>*Balancing*</u>

The following details alignment of the attributes associated with the *balancing* characteristics with the principles associated with the *design* axiom.

- Multiple Perspectives
    - Minimum Critical Specification – Different people, groups, and stakeholders will have different opinions about what constitutes "essential" in terms of ouputs and outcomes. The R&D governance function must consider these multiple perspectives when defining the

essential elements needed for the organization to stay viable over long time horizons and reach its goals.

  - Requisite Saliency – Asking different individuals about the saliency of R&D outputs will reveal different opinions based on their worldview.

- Investment Time and Resources
  - Pareto – Defining what constitutes "good enough" is essential in an R&D environment. The scientific mindset embraces exploration which, in turn, can lead to spending too much time "down in the weeds". For example, 20% of scientific time and resource investment could be driving 80% of the organization's innovational outputs.
- Qualitative and Quantitative Measures
  - Requisite Saliency – Using both qualitative and quantitative metrics allows the organization to develop understanding of what metrics truly mean and what attributable factors are truly important.

Incentivizing

The following details alignment of the attributes associated with the *incentivizing* characteristics with the principles associated with the *design* axiom.

- Incentivization
  - Minimum Critical Specification – People working in the R&D environment must remain motivated to work productively and efficiently while also aligning their efforts with the organization's mission. This requires the system to develop an incentivization structure that will

identify the essential motivators needed to ensure the work force's engagement and compliance.

- Accountability
    - Pareto – If 80% of the outcomes could be achieved by 20% of the means, the organization should have mechanisms in place to identify and make changes to underperforming or poor production areas within the system.
    - Requisite Parsimony – The R&D function must have a mature methodology for documenting the R&D process over long time horizons. Individuals associated with the project cannot be expected to remember the reasoning behind all of their decision points through the development lifecycle.
- Showcasing
    - Requisite Parsimony – Stakeholders may not be able to recall all the efforts generated by the R&D function over the associated long time horizons required to develop the outputs. Showcasing provides an opportunity for the organization to compile and present their progress, processes, and outputs in a meaningful way.
    - Requisite Saliency – Although the R&D organization may believe that they are producing meaningful outputs, stakeholders may believe that certain aspects are more or less important. Showcasing provides a means to communicate the current state of the system and gauge feedback on saliency.

4.3.7 The information axiom alignment. The seventh and final axiom alignment includes the information axiom. The information axioms states that *systems create, possess, transfer, and modify information.* The information principles provide understanding of how information affects systems. The primary principles associated with the information axiom are redundancy of potential command and information redundancy (Adams et al., 2014). The attributes associated with the operational characteristics *evaluating and sharing* were found to align to the *information* axiom. Figure 28 provides the elements included in the alignment process and, again, a detailed description for each follows:

Figure 28: *Information* axiom alignment to operational characteristics

Evaluating	Sharing
• Benchmarking • Metric Assessment	• Internal Transparency • External Transparency • Peer Review

Evaluating

The following details alignment of the attributes associated with the *evaluating* characteristics with the principles associated with the *information* axiom.

- Benchmarking
  - Redundancy of Potential Command – Benchmarking allows organizational leadership to gauge their performance versus competitors to make operational, mission, and management decisions.

- Information Redundancy – Adding benchmarking information will help an organization understand how well they are doing versus their competition. This extra information can be used as a redundancy checksum for decision making.

- Metric Assessment
  - Redundancy of Potential Command – Metric reports provide concatenation of results that can be used to make operational, mission, and management decisions.
  - Information Redundancy – Metric results should be disseminated quickly and concisely. Comparing MOP and MOE results on a common component will provide for better understanding when the results are unclear (noisy).

Sharing

The following details alignment of the attributes associated with the *sharing* characteristics with the principles associated with the *information* axiom.

- Internal Transparency
  - Redundancy of Potential Command – Information shared within the organization provides the management and staff the data needed to make operational, mission, and management decisions. Alternatively, compartmentalization and hiding of information can lead to greater failures.
  - Information Redundancy – Organizations may provide metric evaluation results in both qualitative and quantitative reports. This redundancy in

transmitted information will aid in correcting errors in the interpretation of results.

- External Transparency
    - Redundancy of Potential Command – Information shared external to the organization provides the stakeholders the data needed to make funding and support decisions.
    - Information Redundancy – Organizations may provide metric evaluation results to stakeholder in several forms including statistics, graphs, and language. This redundancy in transmitted information will aid in correcting errors in the interpretation of results.

4.3.8 Detailed systems alignment summary. This section detailed the way in which the system axioms have been used to check for systemic consideration, beyond the GTM, to the operational characteristics. Coverage of each systems axiom has been demonstrated in the detailed mapping. There is no implication made that these are the only principles that may be applicable to the operational characteristics, only that the operational characteristics provide sufficient coverage of the systems axioms to ensure no axioms of systems theory have been ignored. At least one operational characteristic has been associated with each systems axiom. In each case, the association was described using brief descriptions of how characteristic attributes relate to the axiom's associated systems proposition. This provides a significant contribution to the understanding of R&D PMS operational characteristics with respect to systems theory and answers the second research question:

- What systems theory concepts apply to the assessment of performance measurement systems in an R&D environment?

The alignment of operational characteristics and systems axioms provides a significant contribution to the body of knowledge associated with R&D performance measurement systems. This author is aware of no other studies linking R&D PMS operational characteristics to systems theory. With this secondary foundation established, and research question two answered, the research can now move on to results of this dissertation's final phase: the systems based framework for assessment of R&D PMS implementations.

4.4 R&D PMS IMPLEMENTATION ASSESSMENT FRAMEWORK

The first sections of this chapter established the R&D operational characteristics necessary for evaluation of R&D performance measurement systems. The second section detailed linkages between operational characteristics and systems axioms and principles to ensure sufficient coverage from a systems theory perspective. The final section of this chapter builds on these results to develop an operational R&D PMS implementation assessment framework to answer the third and final research question:

- How can R&D performance measurement system implementations be assessed from a systems perspective?

To answer this question, an assessment framework must be developed that would appropriately utilize the identified operational characteristics and associated attributes. The following steps detail the development of this framework. First, the Capability Maturity Model (CMM), a suitable framework basis, is reviewed. Second, an explanation of how the model could be adapted to fit the systems-based R&D PMS context is presented. Third, R&D PMS maturity levels definitions are adapted from the CMM framework. Fourth, the process for aligning the operational characteristics to assessment criteria is defined. Fifth, the R&D PMS implementation assessment framework, based on the results from the GTM and aligned to a systems perspective, is presented. The discussion begins with a review of the CMM.

4.4.1 The Capability Maturity Model. The capability maturity model (CMM) is a widely used framework developed by Carnegie Mellon University's Software Engineering Institute (SEI) to measure process maturity (Paulk, Curtis, Chrissis, & Weber, 1993). Although this model is built to assess organizational maturity in the software development context, its conceptual framework provides a basis for structuring an assessment framework for R&D PMS implementations. Paulk (1993) defines the original five levels that software organization moves through as they strive to reach full maturity. These are:

1) ***Initial***: The software process is characterized as ad hoc, and occasionally even chaotic. Few processes are defined, and success depends on individual effort.
2) ***Repeatable***: Basic project management processes are established to track cost, schedule, and functionality. The necessary process discipline is in place to repeat earlier successes on projects with similar applications.
3) ***Defined***: The software process for both management and engineering activities is documented, standardized, and integrated into a standard software process for the organization. All projects use an approved, tailored version of the organization's standard software process for developing and maintaining software.

4) ***Managed***: Detailed measures of the software process and product quality are collected. Both the software process and products are quantitatively understood and controlled.

5) ***Optimizing***: Continuous process improvement is enabled by quantitative feedback from the process and from piloting innovative ideas and technologies.

Associated with the maturity levels, the methodology uses key processes and key practices to detail the assessment process (Weber, Paulk, Wise, & Withey, 1991). The key processes are the areas that the organization should focus on to improve its processes. Key practices are the details of the policies, procedures, and activities that the organization uses to implement the key process areas and produce indicators. For this dissertation, this assessment framework including the maturity levels, key process areas, and key practices have been adapted to be suitable for R&D PMS implementations. The following section will detail the adaptation and alignment.

4.4.2 Adapting the CMM for R&D PMS implementation assessment. The five levels of maturity, key processes, and key practices detailed in the CMM were adopted for the R&D PMS assessment framework. This required that each be aligned with R&D performance measurement. Key process areas are the process areas that the organization should focus on to improve its process and thus align directly with the R&D PMS operational characteristic detailed earlier in this chapter. To accomplish this, a re-definition of the CMM maturity level definitions was needed. This would serve two purposes. First, it would provide the tailored definitions used for high level understanding of R&D PMS maturity and, second, it would define the inclusion criterion for R&D PMS assessment indicators. The key practices were then developed using the operational characteristic attributes defined earlier in this chapter with respect to maturity level definitions. In summary, the alignment between the CMM and the R&D PMS CMM was constructed as follows:

Key Processes ⇨ R&D PMS Operational Characteristics

CMM Maturity Levels ⇨ R&D PMS Implementation Assessment Levels

Key Practices ⇨ R&D Operational Attributes aligned to CMM Level Maturity

The remainder of this chapter will detail the way in which this research utilized the R&D operation characteristics and attributes to create a R&D PMS capability maturity model.

4.4.3 R&D PMS maturity levels. The tailoring process begins with a re-definition of the five maturity level customized to R&D performance measurement. To accomplish this, the base definitions from Paulk (1993) were adapted to create this alignment. This consisted of removing the software process focus and creating a new focus based on organizational performance measurement. A focus of the re-definition process was maintain the overarching "intent" of each of the maturity levels but remove the contextual alignment to software. These new R&D PMS maturity level definitions, resulting from this re-alignment, are described below:

1) ***Initial***: Performance measurement processes are characterized as ad hoc, and occasionally even chaotic. Few processes are defined, and success depends on individual efforts to collect and interpret information.
2) ***Repeatable***: Basic project management processes and metrics are established to track cost, schedule, and functionality. The necessary process discipline is in place to repeat earlier successes on projects in similar R&D areas.

3) ***Defined***: Processes and measures for both management and engineering activities are documented, standardized, and integrated into a standard measurement process for the organization. All projects use an approved, tailored version of the organization's standard measurement process for developing and maintaining organizational outputs.

4) ***Managed***: Detailed metrics are collected to assess the quality of R&D processes and outputs. Processes and outputs are quantitatively understood and controlled.

5) ***Optimizing***: Continuous process improvement is enabled by a combination of quantitative and qualitative feedback from the performance measurement process and from assessment of R&D innovation and technology outcomes.

4.4.4 R&D PMS key processes and practices. The key processes for the R&D PMS maturity model were defined using a one-to-one correspondence with the operational characteristics detailed earlier in the chapter. The maturity levels and the operational characteristics (key processes) thus become the backbone of the assessment framework. The framework can be represented as a matrix with the operational characteristics becoming the rows and the maturity levels becoming the columns. The R&D PMS assessment framework outline is shown in Table 13.

Table 13: R&D PMS Implementation Assessment Framework Structure

	Level 1 (Initial)	Level 2 (Managed)	Level 3 (Defined)	Level 4 (Predicable)	Level 5 (Optimizing)
Balancing					
Clarifying					
Evaluating					
Evolving					
Humanizing					
Improving					
Incentivizing					
Projecting					
Servicing					
Sharing					
Supporting					
Tailoring					

Populating the remaining cells was accomplished by using the themes associated with the R&D operational attributes (key practices) for each operational characteristic (key process) and assessing them against the maturity expectations for each of the R&D PMS maturity levels. An identical methodology was used for each operational characteristic. The following section details the way in which the key practices were developed to populate the maturity criteria for each operational characteristic.

4.4.4.1 Key practices - Development example. This section describes the process used for developing the key practice indictors for the R&D PMS Maturity Model. The first key process is designated by the first operational characteristic, "Balancing", and will be used as an example to detail the development process. The three attributes associated with balancing are investment time and resources, multiple perspectives, and qualitative and quantitative measures. The GTM process in this dissertation identified the attributes and various themes in practice and supporting literature. These attribute details were reviewed to make a focus list of themes. Details for these themes and attributes can be found in the second section of this chapter. The focus list was then compared to the maturity level definitions. During this process there was no expectation that a one-to-one correspondence would exist between the list of themes and specific maturity levels. However, consideration of all themes was incorporated in the development of the key practices for each key process. In other words, all attribute themes for a given key process, or operational characteristic, can be traced to a key practice indicator within the span of the maturity levels for that key process. The themes established the indicator considerations while the maturity definitions established the criteria for inclusion.

The following example details the way in which each of the key practice indicators was established for the "Balancing" key process. Structurally, the maturity level definition is provided first. The identified key practice indicators are then listed along with each maturity level. Finally, the specific themes associated with each key process indicator are detailed.

Key Process – Balancing (Identified from GTM as operational characteristic) refers to the way in which the PMS must create harmony in the context of time, perspectives, resources, and measurements.

Summary list of themes for balancing includes:

1. Overspending on measurement
2. Spending in inappropriate circumstances
3. Overly complex PMS to understand system

4. Having enough metrics to do the job
5. Maintaining autonomy while incorporating stakeholder requests.
6. Disagreement on metric results.
7. Incorporating public perception
8. R&D rating subjectivity issues
9. Diversification
10. Peer reviews
11. Balancing line manager metric results against holistic system needs
12. Project time lines and budgets
13. Establishing quantitative metrics.

Maturity Definitions and Associated Key Practices (designated by ✓)

1) *Initial* - Performance measurement processes are characterized as ad hoc, and occasionally even chaotic. Few processes are defined, and success depends on individual efforts to collect and interpret information.

   ✓ No requirements or direction for balancing of metrics. This indicator is based on an overview of the key process in an ad-hoc environment.

2) *Repeatable* - Basic project management processes and metrics are established to track cost, schedule, and functionality. The necessary process discipline is in place to repeat earlier successes on projects in similar R&D areas.

   ✓ Metrics consider organizational mission. This indicator considers attribute themes 4, 5, and 12.

   ✓ Primary stakeholder desires considered. This indicator considers attribute themes 5 and 7.

3) *Defined* - Processes and measures for both management and engineering activities is documented, standardized, and integrated into a standard measurement process for the organization. All projects use an approved, tailored version of the organization's standard measurement process for developing and maintaining organizational outputs.

- ✓ Metrics address multiple perspectives. This indicator considers attribute themes 6, 7, 8, 9, and 10.
- ✓ Measurement investment (time and resources) based on expected returns. This indicator considers attribute themes 1, 2, 3, and 4.
- ✓ Metrics linked to project goals and employee performance. This indicator considers attribute themes 2, 4, 11, and 12.

4) *Managed* - Detailed metrics are collected to assess the quality of R&D processes and outputs. Processes and outputs are quantitatively understood and controlled.

- ✓ Metrics throughout the organization address multiple perspectives and are aligned to the R&D mission. This indicator considers attribute themes 6, 7, 8, 9, 10, 11, and 12.
- ✓ Quantitative metrics are used to provide performance statistics to recognize trends and make changes as they are identified. This indicator considers attribute themes 4, 6, 8, 12, and 13.
- ✓ Measurement expense (time and resources) managed based on the organization's ability to use the results to make sound decisions. This indicator considers attribute themes 1, 2, 3, 4, 7, 8, 11, and 12.

5) *Optimizing* - Continuous process improvement is enabled by quantitative feedback from the process and from assessment of the utility of the R&D innovation and technology outcomes.

- ✓ Multiple perspectives are actively solicited but processes exist to limit metrics that could lead to short term focus. This indicator considers attribute themes 5, 6, 7, 8, 9, 10, 11, and 12.
- ✓ Governance reviews metric results from different subsystems and ensures that the established metrics support the overall optimization of the organization. This indicator considers attribute themes 1, 2, 3, 4, 8, 11, and 12.
- ✓ Quantitative metrics are supplemented with qualitative data during analysis for systemic understanding. This indicator considers attribute themes 3, 4, 6, 7, 8, 10, and 13.
- ✓ Measurement expenses (time and resources) are consistently weighed against the expected return and changes made when re-balancing is needed to optimize the PMS. This indicator considers attribute themes 1, 2, 3, 4, 7, 11, and 12.

The identical process was executed for the attributes associated with each operational characteristic, using the themes detailed in Section Two of this chapter, and pooled in a matrix framework. In each case, key practice indicators were developed from a synthesis the attributes and themes for each operational characteristic and tailored to the R&D PMS maturity level. Once this process was completed, the data was put into the final operational format. The final format, representing the R&D PMS implementation assessment framework, provides assessment criteria for all identified operational characteristic for each of the five maturity levels. The operational characteristics are listed in alphabetical order with no ranking implied. The systems-based R&D PMS implementation assessment framework is shown in Table 14.

4.4.5 Intent of application. The systems-based framework for assessment of R&D PMS implementations has been developed to be applicable at the enterprise level of R&D organizations. This provides a significant practical contribution resulting from the theoretical contributions associated with the operational characteristic identification and systems theory considerations. Practitioners using this framework should evaluate each area maturity criteria carefully to understand where their organization currently fits within the framework. As a part of this process, practitioners should utilize the definitions of the R&D PMS Maturity Levels and the Systems-Based R&D PMS Implementation Assessment Framework (Table 14) together to ensure that proper understanding of the concepts intended to be captured during the assessment process. Further, the organization should be able to cite key indicators used by the organization to validate each key practice assessment element. For the purpose of this dissertation, and subsequent applications of the assessment framework, the definition of the key indicator will be:

- Key Indicator – A formal, defined, documented, funded, and governed process used to address an organizational need.

Table 14: The Systems-Based R&D PMS Implementation Assessment Framework

	Level 1 (Initial)	Level 2 (Managed)	Level 3 (Defined)	Level 4 (Predictable)	Level 5 (Optimizing)
Balancing	• No requirements or direction for balancing of metrics.	• Metrics consider organizational mission • Primary stakeholder desires considered.	• Metrics address multiple perspectives. • Measurement investment (time and resources) based on expected returns. • Metrics linked to project goals and employee performance.	• Metrics throughout the organization address multiple perspectives and are aligned to the R&D mission. • Quantitative metrics are used to provide performance statistics to recognize trends and make changes as they are identified. • Measurement expense (time and resources) managed based on the organization's ability to use the results to make sound decisions.	• Multiple perspectives are actively solicited but processes exist to limit metrics that could lead to short term focus. • Governance reviews metric results from different subsystems and ensures establish metric support overall optimization of the organization. • Quantitative metrics are supplemented with qualitative data during analysis for systemic understanding. • Measurement expense (time resources) is consistently weighed against the expected return and changes made when re-balancing are needed to optimize the PMS.
Clarifying	• No processes exist to ensure clarification of expectations or metric relationships to organizational vision	• Performance measures are defined and reviewable. • New metrics requirements communicated but may omit linkage information to outcomes.	• Performance measures are defined using strategies to minimize uncertainty. • Management communicates changes in expectations. • Metric evaluation considers long time horizons associated with R&D outcomes.	• Performance measures developed from multiple perspectives to minimize uncertainty. • Meetings conducted periodically with staff to align understanding of evolving R&D expectations. • Mechanisms are in place to detect issues involving outcome quality and clarify associated expectations over long time horizons.	• Organizational processes use multiple internal and external perspectives to create and refine clear metric expectations. • Peer review used to increase clarity of R&D progress with respect to metric expectations. • Constant communication ensures current understanding of expectations between the people being measured and the metric developers in the emergent R&D environment. • Metric evaluation considers long time horizons associated with R&D outcomes and has course correcting policies in place to deal with issues effecting long term outcomes. • Mechanisms are in place to clarify and align individual, subsystem, and long term mission requirements in evolving conditions to maintain the quality of outcomes.
Evaluating	• Qualitative evaluation based on whatever data are on hand.	• Metric results evaluated at set intervals to make determine problem areas. • Results compared to some standard, such as past results. • Ratings assessed based on qualitative reasoning.	• Metric results evaluated at set intervals and defined processes exist to use the data for course corrections. • SMEs used to define evaluation standards. • Quantitative rating scales used to rate metric results against a standard.	• Metric results detect problem areas. • Methods for evaluating metrics reviewed to understand effectiveness and value added from measurements. • SMEs integrated into the system to define expectations of results. • SMEs provide insight as to measurement result impact on project milestones. • Data used against internal and external benchmarks to define performance achievement.	• Metric results evaluated continuously to uncover problem areas and maintain a positive trajectory. • SMEs, including peer reviewers, integrated into the system to define result expectations and to provide insight as to their impact on both project milestones and long term outcomes. • Evaluation methods updated as new understanding, technologies and evaluation methods emerge. • Data used against internal and external benchmarks to define performance achievement and refine evaluation processes.

(Table 14, Continued)

Evolving	□ Evolution is reactive and chaotic.	□ Metrics results reviewed by leadership to assure consistency of results. □ Processes for handling emergent conditions and funding challenges are not formalized. □ Metric results may be taken at face value making gaming hard to identify. □ Subsystems self-optimize.	□ The PMS analyzes metric results to ensure repeatable outputs. □ Adaptive changes are minimized to promote standardized results. □ Organizational structure addresses R&D funding issues by adjusting metric requirements. □ Gaming issues addressed when identified through variation in expected outcomes.	□ The PMS feedback loop is used to maintain and improve the quality of R&D project management. □ Assessment of metrics leads to adaptive changes. □ Organizational mechanisms designed to provide innovational solutions that maximize expected outcomes in a changing funding environment. □ Periodic monitoring of metric results used to address gaming issues that may exist in the system. □ Peer review used to assist in correction of complex process issues.	□ Organization provides mechanisms for real time monitoring of metric results. □ Organization adapts processes and measures in response to measurement results, peer review, funding changes, and dysfunctional behaviors. □ There are recursive feedback loops throughout the organization to improve sub-system function and optimize R&D high level outcomes. □ Rational for change are communicated throughout the organization. □ Resistance to change is anticipated and leadership has developed strategies to maximize employee buy-in.
Humanizing	□ Human aspects of measurement system not considered.	□ Organization defines positions that are in charge of reviewing metrics and employee performance. □ Employees must go to management to provide feedback.	□ Organization defines job expectations and hires appropriately skilled and responsible individuals are in place to meet organizational metric requirements. □ Feedback from employees solicited during annual evaluations. □ Programs in place to collect employee concerns.	□ Organization defines job expectations and diversified hiring team ensures responsible and skilled individuals are hired to meet organizational metric requirements. □ Employee concerns programs in place and explanations of decisions made to address concerns are delivered to employees when applicable. □ Feedback from employees solicited during annual evaluations, internal audits, and during development of metrics.	□ Organizational strategies exist to hire, develop and retain highly skilled people associated with meeting metric requirements and evaluating results. □ Teams are used to evaluate hiring prospects and processes. □ Supporting systems demonstrate the ability to evaluate competitors and understand and address deficiencies. □ PMS designed, and organizationally supported, to encourage interaction with improvement owners and integration of feedback. □ Counseling made available to organizational employees to help them cope with stressful situation.
Improving	□ Improvement based on leadership intuition.	□ Leadership assigns metric responsibilities to subsystem managers. □ Subsystems develop independent processes to optimize their systems.	□ The organizational members responsible for meeting high level metric goals are clearly identified. □ Roles and responsibilities are clearly defined. □ Learned information from performance measurement is organized and fed back into the system to drive improvement.	□ The organizational members responsible for meeting high level metric goals are clearly identified and evaluated to ensure they produce consistent results. □ Training programs are used to develop skills in employee roles and responsibilities. □ Performance measurement results are evaluated to identify and correct problem areas.	□ The organizational members responsible for meeting high level metric goals are clearly identified, properly trained, supported, and evaluated to assure their ability to produce consistent results. □ Strategies used to predict stakeholder feedback through internal critique. □ Performance measurement results are evaluated to identify problems and optimization opportunities. □ Systemic changes are made with consideration to people, processes, and outcomes.

(Table 14, Continued)

Incentivizing	□ Team work expected under direction of management.	□ Raises tied to employee performance. □ Some form of punitive actions associated with poor performance. □ Measurement showcasing done opportunistically.	□ Raises tied to employee performance using a defined evaluation cycle. □ Formal evaluation processes used to ensure employee accountability. □ The organization reports R&D results to stakeholders at defined intervals.	□ Performance assessment program used to provide annual feedback on employees performance. □ There is organizational awareness of the processes used to evaluate and reward performance. □ Processes exist to address and correct poor performance through training and/or punitive actions. □ Mechanisms are in place to showcase performance of the R&D function to stakeholders and collect feedback and make course corrections as needed.	□ Defined performance assessment program used to provide annual feedback to employees. □ Expectations documented for organizational positions and individual employee expectations. □ There is organizational awareness of the processes in place to reward employees, through financial incentives and/or positions, for outstanding behavior. □ Processes exist to correct poor performance by providing additional training, monitoring, and feedback. □ Processes exist to remove poor performers at all organizational levels for failing to perform to expectations over time. □ Mechanisms are in place to showcase performance of the R&D function to stakeholders, gauge satisfaction, and improve strategies based on feedback.
Projecting	□ Unclear how to make mission and vision actionable.	□ High level metrics developed to align with desired organizational outcomes. □ Low level metrics may not be reviewed for consistency with mission.	□ High level metrics developed to align with the organizational mission, vision and strategy. □ Leadership has an established minimum criteria defined for communicating the mission, vision, and strategy to the entire organization. □ Innovational expectations are outlined in written form.	□ Metrics reviewed prior to implementation to ensure they support the organization's mission, vision and strategy. □ Metric results are analyzed to ensure they produce the mission's intended outcomes. □ Leadership ensures the organization understands the mission, vision, and strategy. □ Innovational expectations are detailed such that skilled staff can be identified and trained to ensure the quality of outcomes.	□ Metrics at multiple organizational levels are aligned with each other to support the mission, vision and strategy and review processes are in place to ensure continuous alignment in emergent conditions. □ Metric analysis clearly identifies opportunities for improvement and mission appropriate corrective actions are enacted in response. □ Leadership ensures employee training and improvement programs align with, and support, the mission, vision, and strategy. □ Strategies used to increase the effectiveness of moving from innovational concept to implementation.
Servicing	□ Organizational direction driven solely by stakeholder desires.	□ Stakeholder interaction may lead to reactive changes. □ Mandates are implemented as required but there is minimal understanding of long term mission impacts.	□ Metric development techniques defined to incorporate stakeholder needs. □ Emergent stakeholder viewpoints and expectations considered and used to change metrics once communicated. □ Defined approaches are used to incorporate stakeholder mandates.	□ Metric development proactively solicits and incorporates stakeholder needs. □ Mandates affecting the organization's mission are evaluated at leadership levels prior to system integration. □ Periodic metric assessment used to evaluate and minimize adverse effects on R&D outcomes.	□ The PMS consistently analyzes, predicts and incorporates stakeholder needs with respect to organizational mission. □ Mandates that effect the organization's mission are incorporated at leadership levels under a defined change control management system. □ Real time metric assessment weighed against long term vision to evaluate and minimize adverse effects on R&D outcomes.

(Table 14, Continued)

Sharing	□ Information reported on a case by case basis.	□ Certain metrics may require reports. □ Information sharing occurs at the leadership levels on a case by case basis. □ External reports prepared as required by stakeholders.	□ Organizational performance information shared internally using a defined report system. □ Reporting results are accessible by relevant management. □ External reports disseminated along with outcome milestones.	□ Organizational performance information shared internally using a defined report system. □ Training available to employees to access and understand report results. □ Reports are accessible by all management levels within the organization. □ External reporting associated with outcome milestones and feedback solicited to assess stakeholder satisfaction.	□ Organizational performance information shared internally using a defined, transparent report system at multiple levels. □ Employees trained to access, understand and provide feedback on report results. □ Reports are accessible by personnel at multiple levels of the organization. □ External reporting associated with outcome milestones and at intermediate intervals to solicit feedback for assessment of stakeholder satisfaction. □ Peer reviews used to demonstrate the quality of outcomes demonstrated through measurement results.
Supporting	□ PMS not integrated into IT system.	□ IT infrastructure may support metric data management but is incomplete. □ Non-uniform support of metric requirements from management.	□ Infrastructure stores metric information and produces reports. □ Organizational leadership provides support for metric requirements and engages staff in the measurement culture.	□ PMS support for metric analysis and reporting integrated into IT infrastructure. □ Consistency of IT infrastructure outputs results ensure quality outputs and outcomes. □ Organizational leadership projects support of metrics and communicates their linkage to specific innovational goals.	□ IT infrastructure provides real time information on metrics to support the PMS. □ IT infrastructure adaptable to contextually specific innovational requirements such as project specific metric reporting and analysis. □ Organizational leadership informs, reviews and projects metric expectations to ensure they support the organization's innovational goals. □ Vision and strategy integrated into measurement culture through communication, training, and leadership support.
Tailoring	□ No clear methodology for metric development.	□ Metrics developed based on the organization's expected outcomes. □ May rely on a template of metrics. □ Many metrics based on meeting project milestones.	□ Metrics developed based on organization's mission. □ Metrics based on meeting project milestones, employee performance, and organizational expectations. □ Most metrics quantifiable and based on MOPs. □ Metrics developed by trained PMS experts.	□ Metrics developed based on organizational mission. □ Formalized processes exist to guide metric development. □ Metrics include both MOPs and MOEs. □ Metrics are created by trained PMS experts and reviewed for appropriateness by qualified individuals. □ Quantifiable measures are used prominently to produce actionable results.	□ Metrics developed based on critical operating issues as they relate to the organization's mission. □ Formalized systems exist to manage the metric development process. □ The organization has highly skilled SMEs that work with scientists and engineers to create, analyze, and assess metric. □ Metrics are developed with consideration to MOPs, MOEs, and COIs. □ Quantifiable measures are used prominently to produce actionable results and SMEs provide qualitative feedback in the assessment of the measurement results. □ Measures are constantly reviewed to assess "value added" and adjustments are made as needed.

Application of the assessment framework should follow a pattern where the organization moves through each key process and evaluates itself against the identified key practices associated with each. As part of this process, the organization must look for key indicators within their respective organization that align to support the intent of the meaning behind each key process and maturity level definition. It should be expected that many organizations will find themselves between levels as they continue to grow, adapt, and mature. A thoughtful and honest assessment process will reveal the strengths and weaknesses associated with the R&D organization's performance measurement system processes. Using the information gleaned from the assessment, the organization can identify opportunities for growth and address problem areas.

4.4.6 SME surveys. SME surveys were conducted to gauge an opinion of the framework's utility from a practical perspective. Although the basis for validity of this research was rooted in the grounded theory method, having a review by SMEs provided an initial assessment of the framework's usefulness and added face validity to the research framework. The survey was designed to assess SME opinion of the framework design and high level definitions. Three questions were developed to gain insight into the usefulness of the proposed maturity level framework design. A target group of four SMEs were identified to receive the survey. These included two SMEs from the public sector and one from the private sector who had been part of the interview process. Additionally, one public sector SME who had not been a part of the interview process was also surveyed. This individual met the same SME qualifications defined previously in Section 0 and had significant past experience in private sector performance measurement. The three survey questions and four SME responses are detailed below.

1. Please rank the usefulness of the maturity levels (with respect to the provided definitions) as a means to assess the maturity areas of R&D performance measurement system implementations. Table 15 describes the results of the survey question.

Table 15: Survey question 1 results

	Not useful	Sufficient	Very Useful	Total	Average Rating
Initial	0% 0	25% 1	75% 3	4	2.75
Repeatable	0% 0	25% 1	75% 3	4	2.75
Defined	0% 0	25% 1	75% 3	4	2.75
Managed	0% 0	25% 1	75% 3	4	2.75
Optimizing	0% 0	50% 2	50% 2	4	2.50

2. Each of the operational characteristics will be evaluated against each of the five maturity levels to assess the state of an R&D performance measurement system implementation. Will comparing the operational characteristics against each maturity level provide an acceptable means to assess R&D performance measurement system implementations? YES / NO. Table 16 describes the results of the survey question.

Table 16: Survey question 2 results

Answer Choices	Responses
Yes	100% 4
No	0% 0
Total	4

3. Please rate the usefulness of the proposed maturity matrix framework (definitions of maturity requirements for each operational characteristic versus maturity level) for R&D performance measurement system assessment. Table 17 describes the results of the survey question.

Table 17: Survey question 3 results

	Not useful	Sufficient	Very useful	Total	Average Rating
R&D PMS Assessment Matrix Usefulness	0% 0	25% 1	75% 3	4	2.75

All respondents agreed that the proposed framework, which rates maturity of each of the 12 operational characteristics, would be an acceptable means for assessing R&D PMS implementations. This initial validation of the framework concept was encouraging. There was some variation in the responses concerning the maturity level definitions and the level of framework usefulness. A review of the individual survey results showed that the private sector SME typically responded one level below the public sector responses for each question. This is true in all cases except the "optimizing" definition rating in the first question, where one public sector SME also responded with a 2, and the final the YES/NO response assigned to the second question. However, this could also be a result of not being able to contact the individual ahead of the survey. All other respondents were contacted verbally prior to the survey being delivered and allowed to have any questions they had answered. However, the private sector SME was only able to be contacted via email. A technical note explaining the operational details of the framework in an application format may provide a more suitable means for distributing information before collecting additional SME data. This provides an interesting opportunity for future research.

4.4.7 R&D PMS implementation assessment framework summary. The final section of this chapter presented the R&D PMS implementation assessment framework. This framework foundation was built on a set of operational characteristics and attributes derived from a grounded theory study detailed in the first and second sections of this chapter. The third section of this chapter detailed the association between operational characteristics and systems axioms. This section introduced the framework that could be used to assess R&D performance measurement through operational characteristics aligned to systems axioms through an adaptation of the Capability Maturity Model. This synthesis of theoretical data with practical application, strengthened by face validation gained from SME surveys, answers the third and final research question:

- How can R&D performance measurement system implementations be assessed from a systems perspective?

This assessment framework, constructed from grounded theory and literature-derived operational characteristics and aligned to systems axioms provides a further significant contribution to the body of knowledge associated with R&D performance measurement systems. This author is aware of no other studies operationalizing an R&D PMS implementation assessment framework using a systems approach. With this third and final question answered, the discussion will conclude with a summary review of the research results, insights and perspectives, and opportunities for further research.

CHAPTER 5

CONCLUSIONS, IMPLICATIONS, AND FURTHER RESEARCH

Chapter 4 presented the analysis and research results used to address each of the research questions posed in this dissertation. This included the identification of operational characteristics resulting from a constructed theory, the alignment to systems principles and axioms to operational characteristics and attributes that ensured systemic coverage of the GTM results, and an operational adaptation of the operational characteristic and their associated attributes to create a systems-based R&D PMS implementation assessment framework. This chapter discusses the research conclusions, insights and perspectives gained throughout the course of the research process, and opportunities for furthering the research associated with the systems-based R&D PMS implementation assessment framework.

5.1 RESEARCH CONCLUSIONS

The purpose of this study was to develop a systems-based framework for the assessment of performance measurement system implementations in R&D organizations to be applicable at the enterprise level by industry practitioners to assess their PMS implementation. Three research questions were framed specifically to address the study's goal of developing the framework:

1. What operational characteristics are necessary for an effective R&D performance measurement system at the enterprise level?
2. What systems theory concepts apply to the assessment of performance measurement systems in an R&D environment?

3. How can R&D performance measurement system implementations be assessed from a systems perspective?

Based on the existing literature, the lack of an existing R&D PMS assessment framework using systems-based approach provided a significant gap which was addressed through this research. This research utilized a grounded theory method, drawing from seven R&D organizations and scholarly literature, to explicitly identify the operational characteristics necessary for the assessment framework. A systematic-alignment of the 12 identified characteristics and 35 attributes to seven systems axioms and 30 systems principles ensured that applicable systems theory considerations were adequately addressed as a result of the research method. Finally, the 12 characteristics were operationalized by framing them within a well known and utilized five level assessment maturity model. This final step was completed using a set of maturity definitions contextually refined for performance measurement system assessment. Face validity gained from SME surveys added further strength and significance to the research. While the methodology used in this dissertation succinctly addressed each of the research questions, this information gleaned from the research can be seen as a starting point from which additional research can be launched. Specifically, several opportunities exist for additional analysis to determine relative importance of categorization and closeness of fit to system concepts. These areas will be talked at in more depth later in this chapter.

5.2 IMPLICATIONS

There are significant implications associated with the theoretically derived framework for assessment of R&D PMS implementations proposed in Chapter 4 of this dissertation. For performance measurement systems theory, it provides a GTM derived basis, based on SME practitioner feedback for the identified operational characteristics. This is significant in that it provides a rigorously derived platform from which further research can be launched. In many other research cases, knowledge is attributed to statistical analysis of data gained from survey ratings. However, this process fails to address a necessary methodological component. Specifically, if the correct questions were posed or if question development could lead directly to the researcher's intended outcomes. The GTM, as used in this dissertation, allows the researcher to refine their thinking and explore new ideas that emerge as a result of communication with other experts in the field in question(Charmaz, 2008). The methodology also provided the basis for credibility and validity while studying the socially embedded subject area where the understanding of phenomena emerged through immersion in the data(Jones & Alony, 2011). The research resulted in a theoretical construct that furthers the state of the existing literature and research in the area of systems-based R&D performance measurement implementation assessment.

The research made significant contributions to the field of engineering management in terms of research methodology through the theoretical development of the operational characteristics, identification of systems theory applicability, and assessment framework methodology. The research questions were addressed using a qualitative approach to look at the phenomena in its natural organizational setting and to develop conclusions based on the problem situation complexity (Leedy & Ormrod, 2010). This methodology was used to determine "the effectiveness of particular policies, practices, or innovations" (Leedy & Ormrod, 2010, p. 137) associated with this research. Insight gained from both practitioners and literature concerning R&D performance measurement, as well as the rigor associated with the GTM, provides the requisite validity and supports the inductive generalization of the framework.

Aside from the framework, the research identified several interesting observations in the course of analysis. One observation concerns the function of the SMEs within organizations. In the case of all subjects interviewed, there was no expert whose singular job was to develop performance measurements. All were tasked with other duties within each organization. In this state, it is unclear to this researcher if organizations at the enterprise level would have the clarity or foresight to ensure proper staffing for the duties associated with the job. The sharing of duties would certainly put a strain on hiring skilled performance measurement professionals if the shared responsibilities demanded other specialized skills needed for the R&D organization. This may help explain the finding that most performance measures are eventually reduced to project management exercises, therefore allowing the performance measurement system to rely on simple measurements of costs and schedule.

Another observation was noted when reviewing interviews from the public and private sectors. It is apparent that a hard delineation between public and private PMS responsibilities does not truly exist in the R&D arena. Both face fairly strong regulation by different government agencies (OSHA, FDA, EPA etc.) which force them both to conform to government mandates. Further, both are subject to external funding from contracts, government, or external divisions. This leads them both to solicit funding based on the selling of innovational "ideas" versus profits made off a product.

Again, noting the 70% PMS failure rate as a result of their implementations (Neely & Bourne, 2000), this dissertation fills a significant gap by through grounded discovery of operational characteristics and the creation of an operational framework for assessment of performance measurement system implementations for R&D enterprise using a systems-based approach.

5.3 FUTURE RESEARCH OPPORTUNITIES

A role of rigorous scholarly research is to identify additional areas of exploration that exist within the associated research domain. This research contributed to the body of scholarly research knowledge relating to R&D PMS assessment by bolstering the area of interest with practical knowledge gained from subject matter experts and decomposed using a rigorous GTM. Still, additional areas of interest exist that provide opportunities for further research exploration and discussion. This section considers the research results discussed in chapter 4 with respect to the current state of scholarly literature in the area of R&D PMS assessment. Drawing upon these issues, the following recommended opportunities are divided into three areas – philosophical issues, theoretical issues, and methodological issues.

5.3.1 Philosophical issues. This dissertation's research presented a philosophical construction based on the worldview of the researcher immersed in the research focus. Future research should address philosophical issues in the domain of PMS assessment. Two of these questions are:

- What might clarify the application of the R&D PMS implementation assessment framework between contextually differing organizations?
- Why do organizations spend so much to measure performance while investing in project managers and schedulers instead of performance measurement specialists?

When addressing these issues one must consider the systemic implications associated with these issues with regards to ontology and epistemology. Turner (2006) asserts that to create a better understanding of personal perspectives, the extreme viewpoints for ontology and epistemology can be referenced to created four distinct combinations. These classifications resulting from the ontological-epistemological combinations are:

- **Conservative relativism** - the doctrine that there is no knowable material reality and no reliable form of knowledge about it either.
- **Social constructionism** - holds that humans cannot access material reality, but that we can access our discourse and subjectivity. Discourse and subjectivity construct our understanding of material reality.
- **Critical realism and contextual constructionism** - hold that there is a material reality which precedes our experiences of it, but that we can only access the entwined relationship between that reality and our perceptions of it. Our reality shapes our discourse and is shaped by it. For contextual constructionism, furthermore, all knowledge is local, provisional and context dependent.
- **Scientific realism** - assumes that there is a material reality, which precedes our experiences of it. Language and numbers provide a means for engagement with and explanation of reality. It holds that science can be fallible, and 'truth' is open to question.

(adapted from Turner, 2006)

Individual belief systems will affect the way in which all problem situations are addressed and improved. R&D organizations are filled with people who have a worldview aligned with scientific realism. This worldview, in turn, drives their thinking about problem situations. Interviews conducted during this dissertation revealed a paradigm where the position of performance measurement specialist was often filled, instead, by schedulers and project managers. This process inevitably leads to the reversion of the R&D performance measurement function to a backwards-looking accounting focus (Hester & Meyers, 2012). As future researchers considers the mentioned questions they must question the worldviews that shape and drive the organizational thinking and decision making in the R&D context and the researcher's individual worldview that will shape the way in which the research is viewed and addressed.

5.3.2 Theoretical issues. Theoretical perspectives emerge from ontology and epistemology. In turn, research methodologies emerge from theoretical perspectives. These perspectives align to the researcher stance on systems philosophy. These theoretical stances lead directly to the way in which research methodologies are selected. At one end of the spectrum, objectivity and realism are prevalent, on the other, subjectivity corresponds to nominalism and a lack of any clear truth. In this continuum, positivism is always paired with objectivism and postmodern could never be objectivist (Opfer, 2008). As an engineer working in a scientific setting, working with others who have post-positivist views is prevalent. This researcher has adopted a pragmatic worldview in which some of the realist arguments in certain contexts are accepted but demand the need to expand preconceived boundaries and address issues contextually. Based on this worldview, the focus of this research framed a problem situation using a rigorous approach to characteristic identification grounded in data from interviews with SMEs. This provides a defensible set of assessment characteristics from which future researchers can expand on using mixed methods and provides some assurance that the right questions will be asked when expanding on R&D PMS assessment research. Theoretical issues that will move this area of research forward include:

- Understanding how the operational characteristics can be further developed through quantitative definition of the ranking or utility for each of the operational characteristics and attributes associated with the assessment framework.
- With regard to the resultant enterprise level assessment framework grounded in operational characteristics, a theoretical approach could be developed to understand how it aligns to a larger sample covering a broader spectrum of organizational dimensions and levels. This would examine the generalizability of the identified concepts and characteristics of R&D PMS assessment.
- How would the categorization of attributes differ if identified through a rigorous alignment of systems principles to each operational attribute?
- Would a re-alignment of categorization based on systems principles affect the PMS assessment perspective?

5.3.3 Methodological issues. The grounded theory method was used to collect and analyze data derived from semi-structured interviews. The research methodology that was employed in conducting these interviews, collecting and analyzing the qualitative data, and developing the theoretical construct was described in Chapter 3. This progression from interview to analysis to theory to framework shapes the research methodology as each research building-block is constructed upon the preceding one (Crotty, 1998). This provides methodological opportunities to continue this building process. Methodological issues that will move this area of research forward include:

- Requiring further development for a quantitative definition of the ranking or utility for each of the operational characteristics and attributes associated with the assessment framework. This understanding would further refine the assessment processes by enabling a statistical priority to be associated with the application of the framework.

- Defining a methodological approach to the systemic alignment mapping of the identified operational characteristics to systems principles.

These research opportunities, while not comprehensive, suggest further topic areas that would provide significant benefits to the current state of knowledge in the area of systems-based performance measurement system assessment.

5.4 SUMMARY

This chapter presented the conclusions and implications identified over the course of this research exploration. This included a review of the research questions and the way in which the results addressed the discovery of R&D PMS operational characteristics, systems theory considerations, and the framework for assessment of R&D PMS implementations. Implications of the research were discussed as they might apply in both scholarly and pragmatic terms. Last, opportunities for future research were discussed to address issues associate with philosophical, theoretical, and methodological areas. These included issues surrounding standardization and generalizability of the R&D PMS assessment application, identification of meta-categories resulting from the alignment of systems principles to each operational attribute, and a rigorous quantitative analysis to define a ranking of operational characteristic utility.

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APPENDICES

APPENDIX A: REVIEWED IRB RESEARCH PROTOCOL

An IRB form was filled out and submitted for review by the ODU IRB. The research was deemed to be exempt.

Baggett Research Protocol

1. Title of proposed study: A Systems-Based Framework for the Assessment of Performance Measurement System Implementations in R&D Organizations

   Primary Researcher: Kenneth S. Baggett Jr.

2. Purpose: To develop a framework that can be used to assess the effectiveness of an R&D organization's performance measurement system implementation.

   Research Questions: Demographic and research. Gender, age, and ethnicity of the participants will not be considered germane to the research questions. A finite number of participants will be interviewed. A grounded theory methodology will be followed and the research will utilize a minimum sample of four, and a maximum of ten, separate regionally based R&D organizations in the interview process. At least two R&D organizations from the public sector and two from the private sector will be included. The research interviews will include questions that identify high level themes associated with performance measurement system implementations as shown in Appendix A. The goal of this dissertation's interviews will be to gain qualitative knowledge that will help to shape the understanding of requirements, challenges, and pitfalls associated with R&D PMS implementations.

3. Procedure
   a. The research design will follow a grounded theory methodology to provide expert insight into the strengths and weaknesses associated with R&D performance measurement system implementation. The data will be used to answer the questions:
      - What operational characteristics are necessary for an effective R&D performance measurement system at the enterprise level?
      - How can R&D performance measurement system implementations be assessed from a systems perspective?

      Interview with SMEs will be used to collect data that will identify themes.

      The coding process will follow the following format:
      1. Create a general sense of the interview data associated with each thread.
      2. Determine underlying meanings and ideas.
      3. Create a list of topics. Cluster where appropriate.
      4. Review the data again using codes as abbreviations for the topics. Identify any new topics.
      5. Turn topics into categories using descriptive names and group where possible.
      6. Create a final code abbreviation for each category and alphabetize the list.
      7. Dissect the data and group it by category to perform the initial analysis.
      8. Re-code data where necessary.

      The coded themes will be used in the output of the research framework.
   b. The interview instrument will be face to face interviews with SMEs. Names of the persons interviewed will not be recorded. A numeric code will be assigned to the interview data to designate it came from a public sector or private sector organization.
   c. The subject's inclusion will be based on the following factors.
      - **Organization maturity**: Subjects organization must have existed and used a PMS for at least 5 years.
      - **Organizational designation**: The subjects organization must be an R&D organization of sufficient size (>50 employees). Public and private organizations will both be included.
      - **Individual Experience**: the subject must possess two or more years of work (individually or as part of a team) experience associated with R&D and PMSs.
   d. The data collection procedures are outlined in the below steps:
      - Selected subjects will be contacted to establish their qualifications with respect to inclusion criteria to set up interview meeting times. They will be emailed a consent form, shown in Appendix B.

- The interview will begin with the researcher providing background on the purpose of the research. A series of interview questions, designed to provide insight into the research questions, will then be asked. Conversations will be tape recorded so that they can be transcribed following the interview. Participants' names will not be asked during the recorded session. A number will be assigned to recordings and transcripts so as to provide enough information to allow interview participants to review the final transcript.
- The data collection is expected to be 30 minutes to 1 hour per participant. This time is dependent on question comprehension speed and the time it takes to respond to the questions.
- Following transcription of the interview recording, participants will receive the opportunity to review the written transcript of the interview and remove statements that they feel have been improperly conveyed or interpreted as well as those they may feel uncomfortable having shared. Once completed, the subject's name will be decoupled from the transcript. The transcript will then be generically added to the cumulative data for coding.

e. All records are kept confidential by assigning a number to each interview participant to ensure anonymity of collected data. Number assignments for the SME/interview correlation will be kept on a secure DOE computer drive separate from the data which employs the latest anti-virus and encryption software. Interview transcripts will be kept on the researcher's personal computer to be coded using a coding software tool. The numbering assignment file and transcripts will not reside on the same computer. Once all interviewees have reviewed their transcripts, their number assignment correlation file will be deleted. Research studies occasionally are evaluated by Institutional Review Boards to determine that the study was conducted properly. If such an evaluation is requested for this study they may have a need to inspect my research record from this study, in order to fulfill their responsibilities.

4. Risks and Benefits for Participation

a. This study poses minimal risk. Benefits are listed below:

- Benefits to Me: No direct benefits other than knowing that participant input will be coded and triangulated to identify common themes associated in performance measurement system implementations.
- Potential Benefits to Society: The results of this data collection will be applied toward the performance measurement implementation assessment framework, which will benefit the greater engineering management community. Specific benefits include the ability of the framework to provide a means for evaluation of an R&D organization's PMS implementation grounded in subject matter expert experience.

b. There are no specified procedures for this minimal risk study.

5. Informed Consent/ Assent: Recruitment of participants will be done by this dissertations researcher. Appendix B addresses research purpose, how data will be used and reported, how confidentiality and anonymity will be maintained, and the process for obtaining informed consent.
6. Human Subject Training Certification
    a. CITI certificate for primary researcher is included in pdf attachment with a completion date of 1/24/13 (Ref # 9574987).

SAMPLE INTERVIEW QUESTIONS

1. How is your organization's Performance Measurement System built to fit its context?
2. How often are performance measures updated?
3. How does the PMS account for new conditions that occur in the system?
4. How is performance measurement information shared?
5. How does your organization currently develop performance measures?
6. What are the strengths of the way measures are selected?
7. What are the weaknesses associated with measures being developed?
8. How does your organization use information from performance measures?
9. What infrastructure does your organization use to support your PMS?
10. What value does the performance measurement system add to the organization?
11. What are the strengths of the PMS that the organization has in place?
12. What could be improved?
13. How does the organization act on information gained from performance measurement?
14. Does the system support the organization's mission?

INFORMED CONSENT FORM

PRIVACY ACT STATEMENT

1. Authority. 5 U.S.C. 301

2. Purpose. Information will be collected for an Engineering Management dissertation titled **A Systems-Based Framework for the Assessment of Performance Measurement System Implementations in R&D Organizations.** The purpose of this dissertation is to develop a framework that can be used to assess the effectiveness of an R&D organization's performance measurement system implementation.

3. Routine Uses. The data collected will be used for developing a framework of high level categories and dissertation work conducted for a Doctor of Philosophy in Engineering Management at Old Dominion University. I voluntarily agree to its disclosure to the agencies identified above, and I have been informed that failure to agree to this disclosure may make the research less useful.

4. Voluntary Disclosure. Provision of information is voluntary. Failure to provide the requested information may result in failure to be accepted as a research volunteer in an experiment or removal from the program.

INFORMED CONSENT FORM FOR RESEARCH: A Systems-Based Framework for the Assessment of Performance Measurement System Implementations in R&D Organizations

1. **Introduction:** You are being asked to voluntarily participate in a dissertation entitled "*A Systems-Based Framework for the Assessment of Performance Measurement System Implementations in R&D Organizations* ". The main objective of this form is to assure that you are informed of the risks and benefits of this research and that your participation is voluntary.

2. **Purpose of the study:** The purpose of this is to develop a framework that can be used to assess the effectiveness of an R&D organization's performance measurement system implementation. Interview with SMEs will be used to collect data that will be coded to identify themes. The coded themes will be included in the output of the research framework. Selected subjects will be contacted to set up interview meeting times. The interview will begin with the researcher providing background on the purpose of the research. A series of interview questions, designed to provide insight into the research questions, will then be asked. Conversations will be tape recorded so that they can be transcribed following the interview. Participants' names will not be asked during the recorded session. Following transcription of the interview recording, participants will receive the opportunity to review the written transcript of the interview and remove statements that they feel have been improperly conveyed or interpreted as well as those they may feel uncomfortable having shared.

3. **Procedures to be followed**: The research design will follow a grounded theory methodology to provide expert insight into the strengths and weaknesses associated with R&D performance measurement system implementation

4. **Discomforts and Risks:** This study poses no more than minimal risk.

5. **Benefits:** The benefits to society and me are described below:
   (a) Benefits to Me: No direct benefits other than knowing that participant input will be coded and triangulated to identify common themes associated in performance measurement system implementations.
   (b) Potential Benefits to Society: The results of this data collection will be applied toward the performance measurement implementation assessment framework, which will benefit the greater engineering management community. Specific benefits include the ability of the framework to provide a means for evaluation of an R&D organization's PMS implementation grounded in subject matter expert experience.

6. **Duration/Time of the Procedures and Study:** The data collection is expected to be 30 minutes to 1 hour per participant. This time is dependent on question comprehension speed and the time it takes to respond to the questions.

7. **Alternative Procedures that Could be Utilized:** N/A

8. **Statement of Confidentiality:** All records are kept confidential by assigning a coded identification number to your transcripts. Transcripts and numbering assignment files will be kept on separate computers. Taped interviews will be deleted once transcribed. The confidentiality of the information related to my participation in this research will be ensured by maintaining transcripts only coded by identification numbers. Research studies occasionally are evaluated by Institutional Review Boards (IRB) to determine that the study was conducted properly. If such an evaluation is requested for this study they may have a need to inspect my research.

9. **Right to Ask Questions**: You have a right to ask questions at any time before, during, or after the survey. Please contact the Principal Investigator, one of the Associate Investigators, or the Institutional Review Board (IRB) chairman at any time with questions, complaints or concerns about the research. They are:
   Principal Investigator: Kenneth S. Baggett, 757-871-2501, baggett@jlab.org

10. **Payment for Participation:** N/A

11. **Cost of Participating:** N/A

12. **Voluntary Participation:** Your participation is voluntary and you may request to withdraw or stop the survey at any time without free of reprisal or penalties.

13. **Injury Clause:** N/A

14. **Participation Requirements:** There are no requirements for the participants.

If you agree to take part in this research study and the information outlined above, please sign your name and indicate the date below. By signing below, you are also certifying that you have been informed of the information above and that your participation in this study is voluntary. You will be given a copy of this signed and dated consent form for your records.

Participant's Name **Participant's Signature** **Date**

Principle Investigator's Name **Principle Investigator's Signature**

PRIVACY ACT STATEMENT

I understand that all personal information will be kept confidential and will be reported in an anonymous fashion. This includes, but is not limited to, my name, rate, rank, years of experience, and performance during this study. I further understand that disclosure of personal information is voluntary, and I may withdraw this consent at any time without penalty.

______________________________ ______________

Participant's Signature **Date**

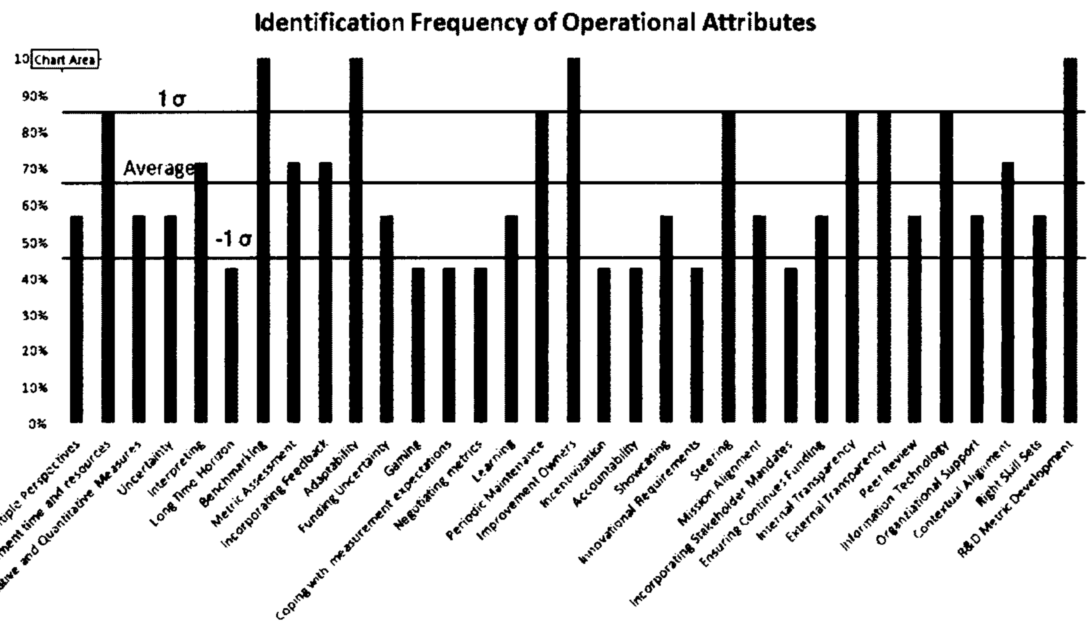
______________________________ ______________

Principal Investigator's Signature **Date**

APPENDIX B: OPERATIONAL CHARACTERISITCS AND ATTRIBUTES

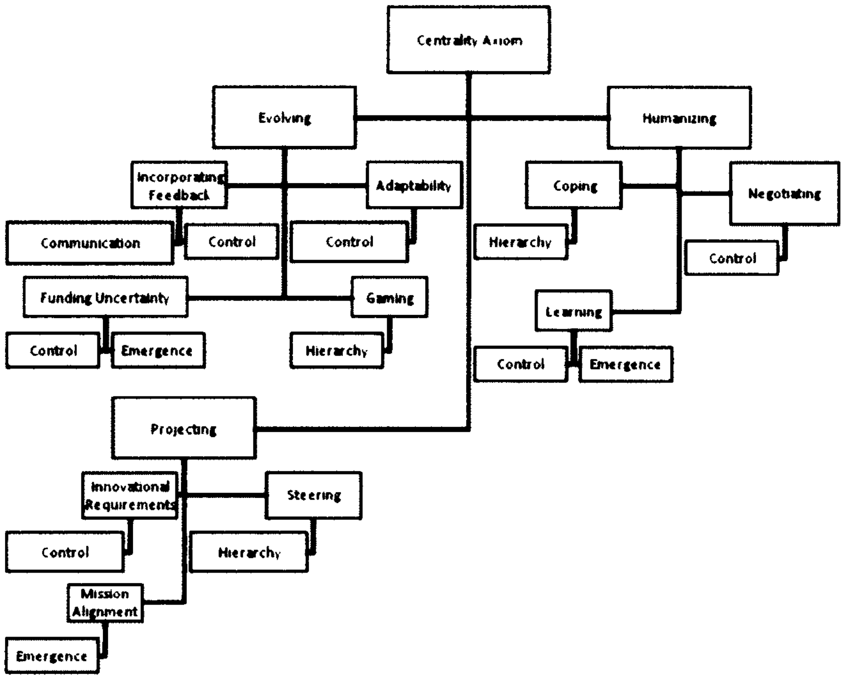
Balancing	• Investment Time and Resources • Multiple Perspectives • Qualitative and Quantitative Measures
Clarifying	• Interpreting • Long Time Horizon • Uncertainty
Evaluating	• Benchmarking • Metrics Assessment
Evolving	• Adaptability • Funding Uncertainty • Gaming • Incorporating Feedback
Humanizing	• Coping with Measurement Expectations • Learning • Negotiating Metrics
Improving	• Improvement Owners • Periodic Maintenance
Incentivizing	• Accountability • Incentivization • Showcasing
Projecting	• Innovational Requirements • Mission Alignment • Steering
Servicing	• Ensuring Continued Funding • Incorporating Stakeholder Mandates
Sharing	• External Transparency • Internal Transparency • Peer Review
Supporting	• Information Technology • Organizational Support
Tailoring	• Contextual Alignment • R&D Metric Development • Right Skill Sets

APPENDIX C: FREQUENCY OF ATTRIBUTE IDENTIFICATION

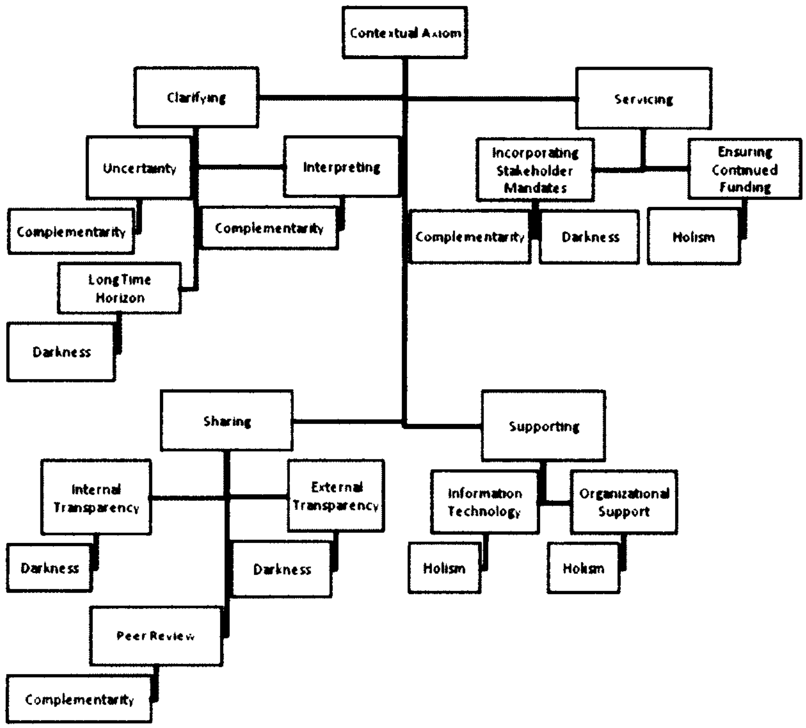


APPENDIX D: SYSTEMS ALIGNMENT DIAGRAMS

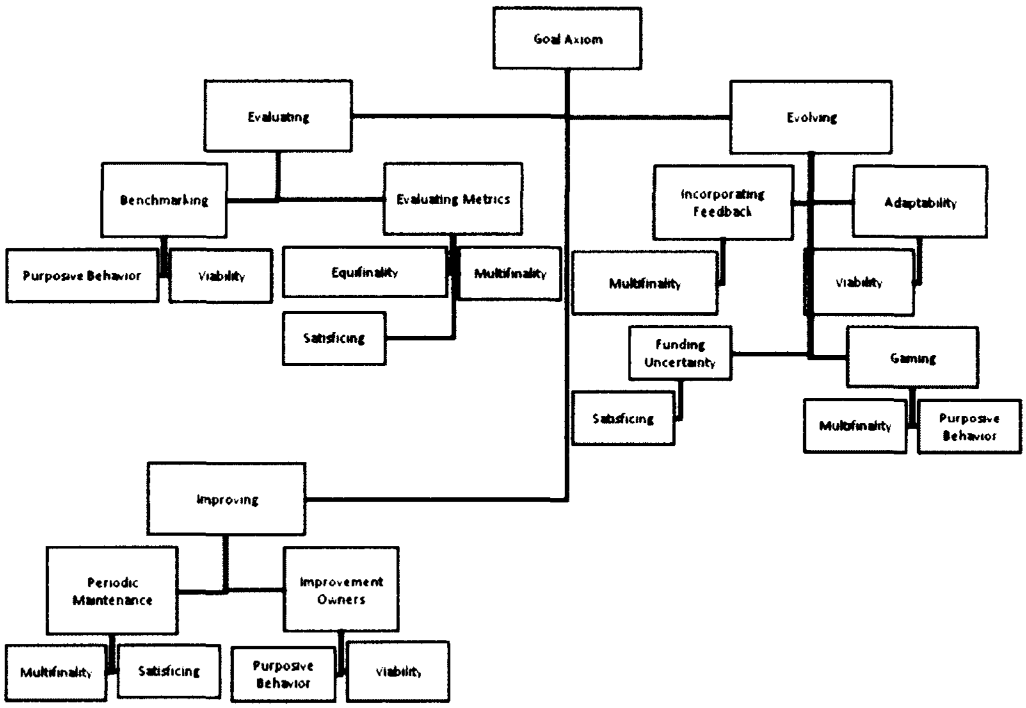
Centrality Axiom Alignment to Operational Attributes



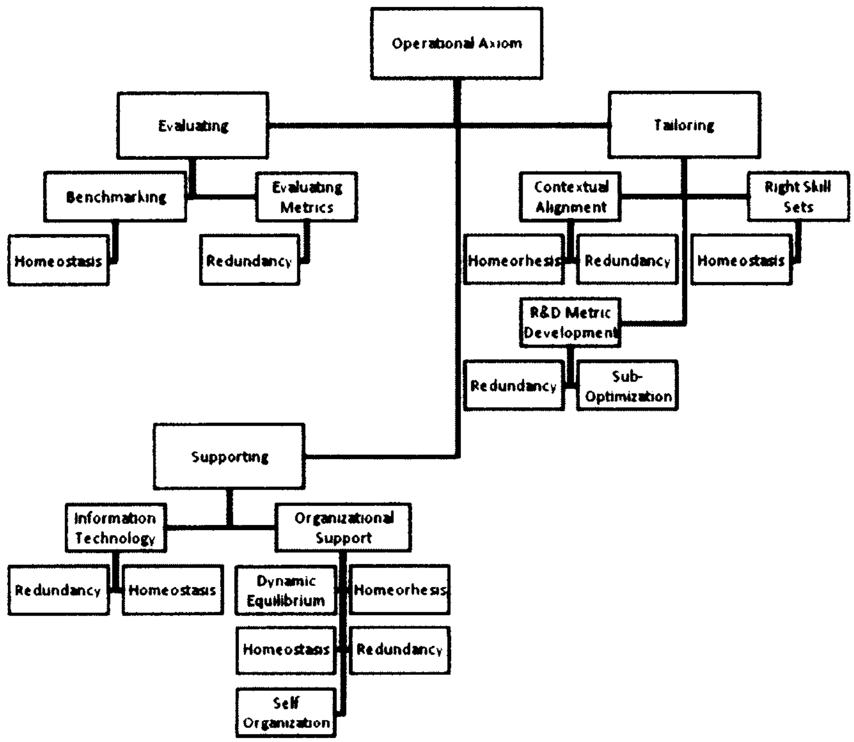
Contextual Axiom Alignment to Operational Attributes



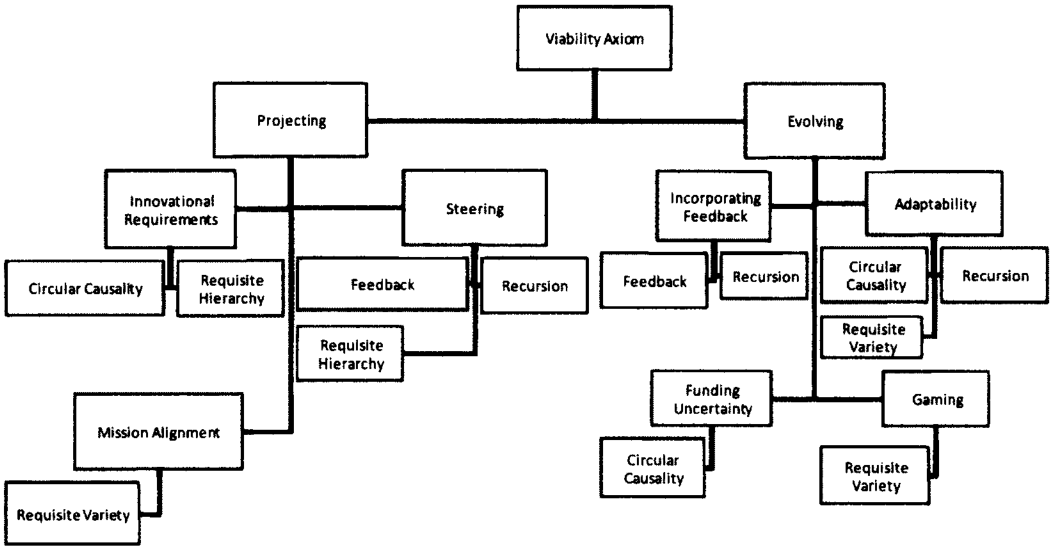
Goal Axiom Alignment to Operational Attributes



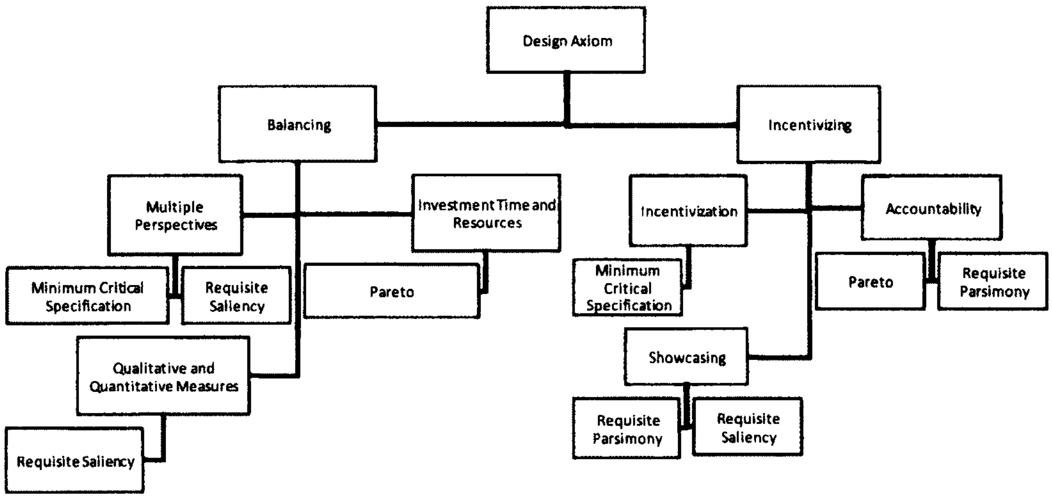
Operational Axiom Alignment to Operational Attributes



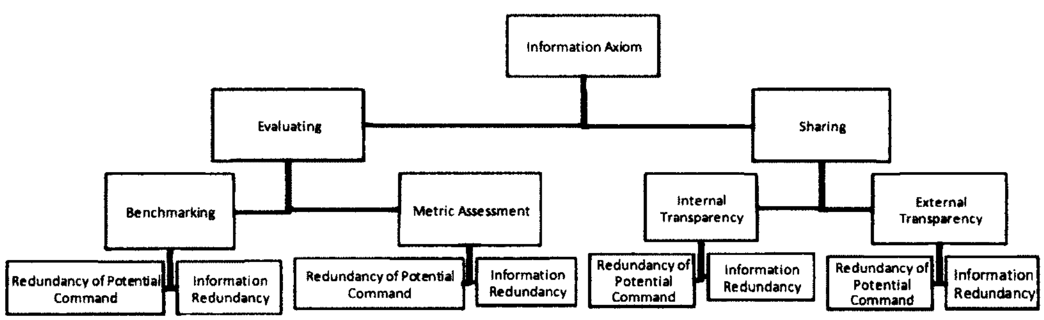
Viability Axiom Alignment to Operational Attributes



Design Axiom Alignment to Operational Attributes



Information Axiom Alignment to Operational Attributes



VITA

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Doctor of Philosophy (Engineering Management and Systems Engineering), Old Dominion University, 2014
Master of Science (Applied Physics and Computer Science, Computer Instrumentation Engineering), Christopher Newport University, 2006
Master Certificate (Software Design and Development), Christopher Newport University, 2005
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PROFESSIONAL EXPERIENCE:

Jefferson Lab 2000-present
Electrical Engineering Systems Liaison to Accelerator Operations (2013 - present)
Magnet Measurement Group Leader (2006 - 2013)
Survey and Alignment Engineer (2000 - 2006)
Davis and Associates Land Surveyors 1996-2000
Surveyor Crew Chief
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Newport News Shipbuilding 1989-1992
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SCIENTIFIC AND PROFESSIONAL SOCIETIES MEMBERSHIPS:

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PUBLICATIONS:

- "Built to Fail? A literature Review of Problems with Implementation and Assessment of Performance Measurement Systems in R&D Organizations", TIIJ Fall/Winter 2013.
- "Developing Stakeholder Incentives to Encourage Effective Governance", American Society for Engineering Management Conference Proceedings pg. 13-16, 2010.
- "Design, Assembly, Optimization, and Commissioning of a Rotating Coil, Multipole Magnet Measurement System for the Thomas Jefferson National Accelerator Facility", Thesis, CNU 2005
- "Magnetic Measurement of the 10 KW, IR FEL 180 Degree Dipole ", PAC 2003