AN EFFECTIVE IMPLEMENTATION OF OPERATIONAL INVENTORY MANAGEMENT

A Record of Study

by

SIVAKUMAR SELLAMUTHU

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF ENGINEERING

May 2009

Major Subject: Engineering
College of Engineering

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Approved by:

Co-Chairs of Committee,	Guy L. Curry
	F. Barry Lawrence
Committee Members,	Brett A. Peters
	Donald R. Smith
Coordinator of Graduate Programs,	Robin L. Autenrieth

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ABSTRACT

An Effective Implementation of Operational Inventory Management. (May 2009)

Sivakumar Sellamuthu, B.E., PSG College of Technology;

M.S., Texas A&M University

Co-Chairs of Advisory Committee, Dr. Guy L. Curry
Dr. F. Barry Lawrence

This Record of Study describes the Doctor of Engineering (DE) internship experience at the Supply Chain Systems Laboratory (SCSL) at Texas A&M University. The objective of the internship was to design and develop automation tools to streamline lab operations related to inventory management projects and during that process adapt and/or extend theoretical inventory models according to real-world business complexity and data integrity problems.

A holistic approach to automation was taken to satisfy both short-term and long-term needs subject to organizational constraints. A comprehensive software productivity tool was designed and developed that considerably reduced time and effort spent on non-value adding activities. This resulted in standardizing and streamlining data analysis related activities.

Real-world factors that significantly influence the data analysis process were identified and incorporated into model specifications. This helped develop an operational inventory management model that accounted for business complexity and data integrity issues commonly encountered during implementation. Many organizational issues including new business strategies, human resources, administration, and project management were also addressed during the course of the internship.

DEDICATION

To my mother, father, brother, and Guru

ACKNOWLEDGEMENTS

At the outset, I would like to mention that it feels rather surreal to be completing a doctorate given that up until my enrollment in the program, it hardly figured in my career plans. Time and circumstances have proven otherwise, but not without many an individual's support, guidance, and well wishes. At this juncture, I make a humble effort to thank and express my gratitude to them.

Firstly, I would like to thank Dr. Guy Curry for his support and patience as my committee co-chair to help navigate the unique needs of the Doctor of Engineering (DE) program. I am grateful to him especially for his advice on my academic course plan that truly transformed my thought process to a great extent, sharpened my learning abilities, and helped in better assessing my true interests all of which eventually led me to making an informed decision about my doctoral program type.

I am ever grateful to my committee co-chair and more appropriately my mentor Dr. Barry Lawrence for providing me with excellent career opportunities during my years at Texas A&M including the DE internship. It was a valuable and rewarding experience to have worked for him as both a graduate assistant and a full time research staff at the Supply Chain Systems Lab (SCSL) which has had a profound impact on my overall personality development and work performance. I cannot thank him enough for his support, friendship, and motivation that undoubtedly helped me gain self-confidence. He will continue to be a source of inspiration for the rest of my life.

I would like to thank my committee member Dr. Brett Peters for his support and insight. My first ever class at Texas A&M under him demonstrated the importance of automation which in fact became a crucial part of the DE internship. Similarly, committee member Dr. Don Smith's classes and advice on the DE program provided a proper structure to the internship work and report for which I am grateful to him.

I am also thankful to Dr. Richard Alexander, Dr. Walter Buchanan, Ms. Kaye Matejka, and Bharani Nagarathnam for their administrative support and guidance in helping me conduct my internship at the SCSL in spite of some unique requirements. Along the same lines, I would like to thank Ms. Judy Meeks and Ms. PeggyJo Johnson for assisting me in accomplishing several administrative tasks in a timely manner.

I am indeed glad to have had the opportunity to work with many bright minds at the SCSL. Numerous brainstorming sessions and technical discussions shaped up much of my problem-solving thought process and solution approach. The team environment certainly had an impact on my internship contributions and professional outlook in general. For their invaluable feedback and support, I am thankful to my colleagues and friends Pradip Krishnadevarajan, Senthil Gunasekaran, Brijesh Rao, Praveen Kuttuva, Maharajan Chidambaram, and Manikandan Ramaswamy. I am also appreciative of several other colleagues at the Industrial Distribution program for having provided a wonderful opportunity and environment to work and collaborate with.

In retrospection, this opportunity which in fact I consider to be a stroke of serendipity, would not have materialized if not for my mother Ruckmani's vision and persuasion to let me take up higher studies. Needless to say, I am ever indebted to this most beloved person for her love, advice, prayers, support, and faith. Of course, I would like to thank my father Sellamuthu, brother Balaji, and other relatives and family friends for their encouragement and well wishes.

Finally, I consider myself to be very lucky to have had the opportunity to spend the early years of my career at a unique institution like Texas A&M that embraces knowledge frontiers while being firmly rooted in life values such as integrity, character, and tradition. I am much obliged to this great University that has taught me perhaps one of the most important lessons of "learning how to learn" and will cherish this memorable experience forever.

NOMENCLATURE

DE	Doctor of Engineering
ERP	Enterprise Resource Planning
GM	Gross Margin
GMROII	Gross Margin Return on Inventory Investment
ID	Industrial Distribution
IT	Information Technology
ROI	Return on Investment
ROP	Re-order Point
SCSL	Supply Chain Systems Laboratory
SKU	Stock Keeping Unit

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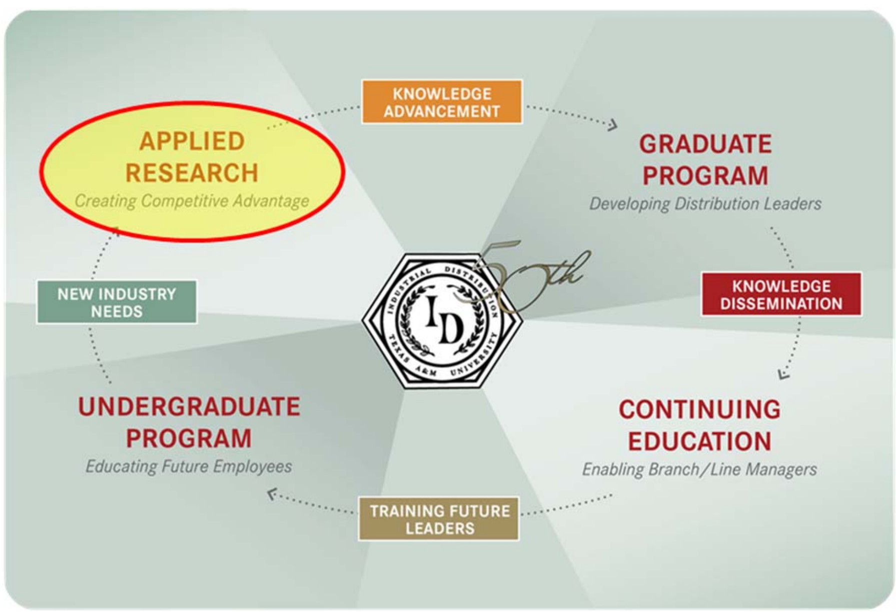
1. INTRODUCTION

A brief introduction about the Supply Chain Systems Lab (SCSL) where my Doctor of Engineering (DE) internship was conducted is given in this section. An overview of the internship scope and objectives is also provided.

1.1 About the Supply Chain Systems Lab

The Supply Chain Systems Lab (SCSL) is the research arm of the Industrial Distribution (ID) Program at Texas A&M University and was officially established in Spring 2003. As can be seen in Figure 1.1, the lab plays a critical role in the ID program's mission of knowledge creation and dissemination.

Figure 1.1 Role of the Supply Chain Systems Lab

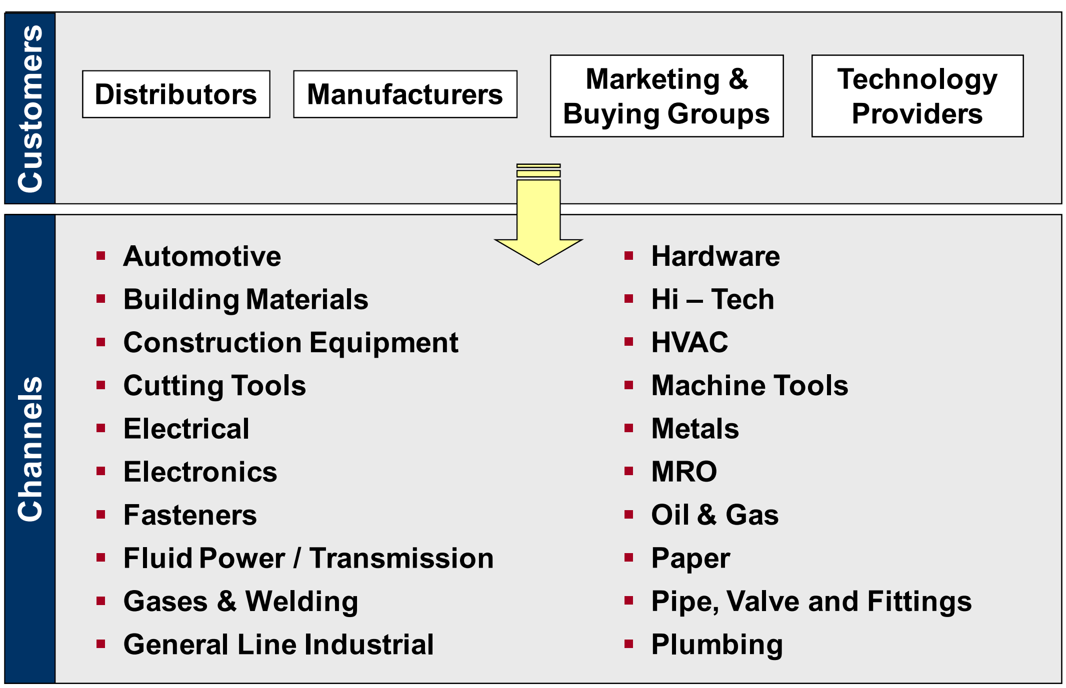


This Record of Study follows the style of *Management Science*.

SCSL is the nation's premier distribution focused lab providing state-of-the-art research solutions and services to the industrial distribution business community. The lab conducts applied research projects and consortiums with a mission to provide competitive advantage for its clients and create cutting-edge knowledge.

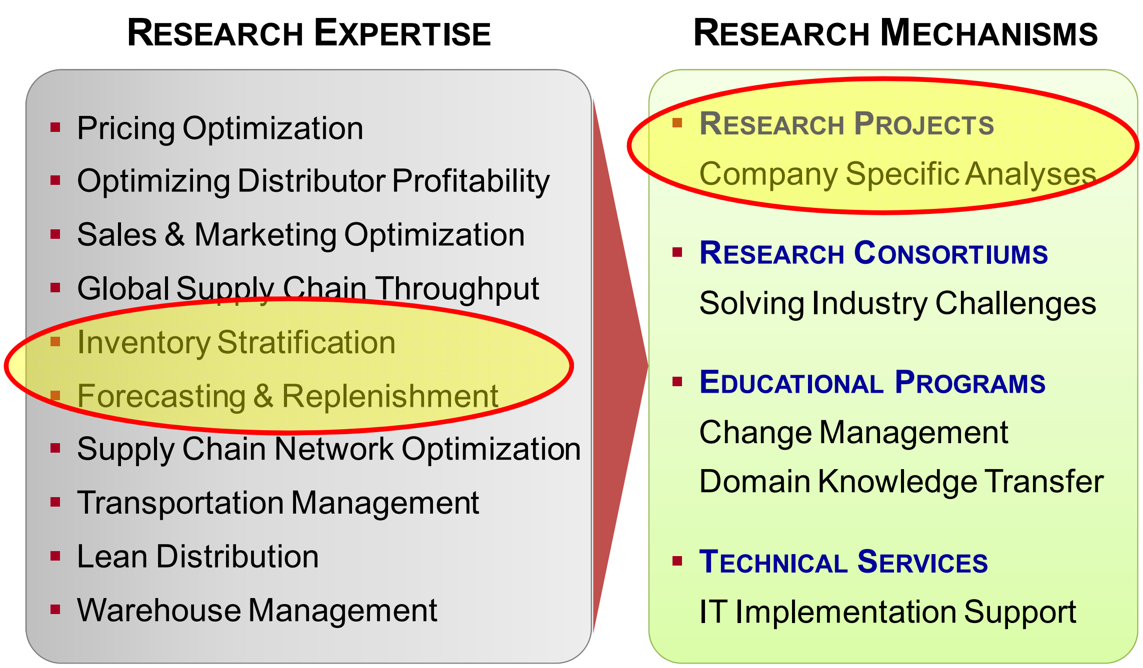
The majority of SCSL's clientele are industrial distributors, especially small and mid-sized firms, but the client base also encompasses manufacturers, technology providers, and buying groups. Also many times, an industrial distributor's role overlaps with that of others in the supply chain depending upon their channel, business complexity, and a variety of such factors. Examples include value-add activities performed by metal distributors, manufacturing and service operations offered by oil field services companies, etc. Figure 1.2 gives an overview of the industrial distribution supply chain along with some of the key channels.

Figure 1.2 SCSL Customer Base and Channels



The research solutions and services offered by the lab are on a variety of business topics as illustrated in Figure 1.3. The focus of this report, however, will be on the topic of inventory management (i.e., Inventory Stratification, Forecasting, and Replenishment analyses) in the context of company-specific research projects that involve highly customized data analyses and best practice policy recommendations.

Figure 1.3 SCSL Research Solutions and Internship Focus



1.2 Internship Scope and Objectives

My DE internship was conducted at the SCSL from Fall 2004 to Summer 2005 which was also the timeframe when the lab witnessed an exponential growth in the number of funded research projects together with an increase in the level of project complexity. When the US economy gained momentum after the dot-com crash, the distribution community came under pressure to improve their business performance (profitability and return on investment) especially given the critical role of a distributor in a service based economy. This made them seek professional help on scientific methodologies and best practices which led to a flurry of projects for the SCSL. Given that inventory is the largest asset for a distributor, it was not surprising to see the focus in this area.

A project that was of considerable relevance to the internship was the Wilson inventory management project which kick-started during the middle of 2004. Wilson, a pipe-valve-fittings distributor, is based out of Houston catering largely to the oil and gas industry. Wilson, being well positioned for an exponential business growth in 2005/06, wanted to quickly right size its inventory levels in time for the upturn in the oil industry. At that point of time, this was one of the most complex projects ever undertaken by SCSL given the size of the company, their aggressive growth strategy, business intricacy, large number of inventoried locations, and need for a quick turn-around of analysis results.

The Wilson project, first off, warranted a *high level of data analysis automation* compared to the then existing ad-hoc manual procedures at SCSL. But it became apparent that the automation process, when designed and deployed in a holistic way, can be useful for several other projects too. Secondly, based on previous project experiences, there was going to be a *need for adapting and/or extending theoretical models* while addressing real-world business complexity and data integrity issues. As a growing organization, there were also many *organizational challenges and issues* at SCSL that had to be addressed. Table 1.1 describes some of the key internal and external organizational challenges.

Table 1.1 Organizational Challenges

Internal Challenges	External Challenges
▪ Evolving knowledge base ▪ Exponential increase in no. of projects ▪ HR constraints (lack of tactical skillset) ▪ Lack of proper IT infrastructure	▪ Project scope creep ▪ Mix of hypo- and hyper-responsive clients ▪ Unsophisticated end-users

Hence, the internship's objective was to use the Wilson inventory project as a foundation to establish a solid automation process and develop an operational level inventory management model while working within the internal and external organizational constraints. Although the scope of the internship was limited to inventory management, several of the solution approaches and decision-making processes are generic enough to be applicable to other areas. More details about the internship final objectives are provided in APPENDIX D for reference.

The internship activities and the overall experience can be categorized into 3 broad areas as given below and the forthcoming sections have been organized accordingly. Each section provides details on specific needs, challenges, key contributions, and benefits:

- **Technology:** The section "A Holistic Approach to Data Analysis Automation" describes how information technology was leveraged to quickly develop a comprehensive productivity tool in order to drastically reduce workloads and ultimately establish a sustainable process for data analysis tasks.
- **Science:** The section "Inventory and Information Management in Practice" addresses the practical challenges faced, particularly business complexity and data integrity issues, when implementing theoretical concepts and the relevant solution methodologies.

- **Management:** The section "Organizational Challenges and Solutions" describes key managerial and administrative (non-technical) issues tackled during the course of the internship.

In essence, the internship required me to play the role of a *tactical manager* having a clear understanding of both the strategic organizational goals and the operational realities. The key was to analyze available resources and *orchestrate* the best way to perform activities in order to maximize and more importantly sustain the overall benefit.

2. INVENTORY MANAGEMENT IN DISTRIBUTION FIRMS

In order to help set the context for the rest of this report, this section gives an overview of a distributor's key business functions, inventory's role in determining a company's return on investment, and the importance and challenges of operational inventory management in industrial distribution firms.

Despite the fact that the wholesale distribution industry is a large sector of the US economy, the level of automation and practical implementation of cutting edge business process improvement tools such as Inventory Optimization and Lean / Six Sigma is surprisingly minimal. But the industry started to embrace the state-of-the-art scientific tools and techniques in the recent years due to several reasons. The 90's shift in the US economy from a manufacturing-based to a service-based economy brought the distribution community's critical role in the new supply chain era to prominence hence forcing them to improve their business performance.

2.1 Inventory and Return on Investment (ROI)

The wholesale distribution industry is a highly fragmented industry and consists of a multitude of small and mid-sized companies many of which are family owned. The ultimate goal of these companies (or rather any for-profit company) is to optimize shareholder value which, in financial terms, translates into increasing profitability and ROI.

A company achieves profitability improvement by increasing gross margins through better pricing management and/or reducing operating expenses through operational excellence. Return of Assets (ROA), a ratio of profitability and total investment in assets, is a form of ROI which increases whenever profitability (the numerator) increases. But significant ROI improvements are achieved through reduction in total assets (the denominator), specifically inventory in the case of distribution companies, due to the following reasons:

- Typical firms tend to agree that they have more assets than necessary and a “housekeeping” operation can trim their asset levels without causing a major impact on customer service.
- Inventory is the largest asset for a distributor and is the least risky one to manipulate compared to facilities, equipment, human resources, etc.
- ROI targets are often set on tight timeframes (due to pressure from the shareholders and Board of Directors) and inventory reduction is normally the quickest way to achieve them compared to other initiatives such as pricing / lean.

2.2 Inventory Management Processes

Although inventory management is often associated with and comes under the purview of Operations personnel, in reality Purchasing and Sales Force too are stakeholders since these three business functions strive to minimize various interrelated cost components – holding cost, ordering cost, stock-out cost – that are directly impacted by inventory.

From the viewpoint of data analyses and business processes, inventory management gets broadly classified into three major areas as follows:

- **Inventory Stratification:** Prioritization of critical items.
- **Forecasting:** Prediction of customer demand.
- **Replenishment:** Determination of safety stocks, re-order points, order quantities.

As mentioned earlier, inventory reduction is almost always the starting point for companies (distributors in particular) attempting to increase ROI. Also it has a significant impact on cash flow which is especially critical for small and mid-sized companies. When the ROI requirement is considered together with the above three inventory management processes, the best practice processes can be fundamentally categorized into two types based on their nature, outcome, and timing of ROI impact. Table 2.1 illustrates this idea of *right-sizing* (inventory stratification) versus *fine-tuning* (forecasting and replenishment) inventory levels.

Table 2.1 Nature of Inventory Management Processes

Analysis	Process Nature	Operational Outcome	ROI Impact
Inventory stratification	Housekeeping / Right-sizing	▪ Reduction of excess inventory ▪ Re-deployment (increase in sales)	Immediate to short-term
Forecasting & Replenishment	Fine-tuning / Streamlining	▪ Focus on critical items (increase in HR efficiency) ▪ Improvement in customer service	Long-term

2.3 Practical Implementation Challenges

It is clear then that inventory management best practices can have a significant impact on a company's profitability and ROI. Yet, a review of SCSL's history of inventory projects clearly shows that companies continue to struggle even with a seemingly simple process such as inventory stratification which is essentially ABC analysis that is traditionally performed by ranking products, say, according to a sales or revenue based 80-20 (Pareto) rule. The reason is that however simple a methodology appears, in practice it is extremely difficult to appropriately account for and align all the relevant factors with respect to people, process, technology, and data. Listed below are several factors that significantly impact the successful implementation of inventory management best practice processes at an operational level.

2.3.1 Business Complexity

The ground reality of day-to-day operations in a company involves several business factors and decision variables that both information systems and humans strive hard to keep up with. The critical factors are listed below along with a few associated parameters / examples:

- **Location attributes:** Types of location, Organizational roll-up structure.
- **Product attributes:** Product mix, Unique product families, SKU proliferation.
- **Transactional attributes:** Delivery modes, Returns, Multiple shipments.
- **Overarching business factors:** Industry type, Costing policies.
- **Customer relationships:** Contract vs. Non-contract, Core vs. Marginal.
- **Supplier relationships:** Branding, Exclusivity, Single or sole sourcing.

2.3.2 Data Quality

The permutations and combinations of the real-world business factors, such as the ones mentioned above, translates into myriad transactional data types / patterns that routinely get captured and processed by the information systems. Needless to say, achieving quality in this transactional data recording and retrieval process will continue to pose a significant challenge but will ultimately determine the effectiveness of business decisions that rely on system information. For any analysis program to be successfully implemented within information systems, it is fundamental to ensure availability of relevant data, proper data specifications, and innovative solutions to data integrity issues.

2.3.3 Information System Capability

Most of the firms, small and mid-sized distributors in particular, still run on Information Technology (IT) systems designed for the 80's and 90's when the computational power was at a premium. The level of sophistication in analysis methodologies implemented within those systems was often governed by the system limitations. Although information systems have come a long way since then, it will take years if not decades for majority of the businesses to adopt state-of-the-art systems due to several reasons like affordability, implementation time and resources required, learning curve with new systems, uncertainty of return on major IT investments, etc.

2.3.4 Change Management

Perhaps the biggest hurdle to successful implementation of a new process in a company is change management. Overcoming issues related to process, data, and technology will be of little use if there is no buy-in from people, the ultimate decision-makers. Some of the key factors relevant to change management are as follows:

- **Organizational size and culture:** Open to change, quick adaptability, holistic approach to problem-solving and decision-making.
- **Performance metrics:** Alignment of individual and company goals.
- **Top management commitment:** Follow-through, accountability.
- **End-user sophistication:** Level of maturity in embracing technology tools.

3. A HOLISTIC APPROACH TO DATA ANALYSIS AUTOMATION

Technology is the lynchpin for increasing efficiency but is often relegated to a poor status than what it truly deserves. According to the Lean Enterprise Research Center (Hines and Taylor 2000), in information intensive environments (like office), only 1% of the activities are *value-adding*, 49% are *necessary non-value adding* and 50% are simply *non-value adding*. This shows that there is significant scope for work efficiency improvements.

When considering the above in the context of SCSL activities, the room for improvement lies in data analysis related tasks since they constitute the majority of typical project activities. Data handling tasks are invariably performed using technology tools and hence effective use of those tools holds the key to reducing non-value adding activities. This section describes how information technology tools were leveraged to drastically reduce workloads by streamlining data analysis related tasks and more importantly, achieve that in a sustainable way.

The first tactical step of the internship, as mentioned earlier, was to automate data handling / processing for the Wilson inventory project. Specifically, there were three key requirements as listed below:

- **Repetitive analysis runs:** It was expected from Wilson that all key executives would get the opportunity to thoroughly review the analysis results until they felt comfortable to take any action based on the information. This meant that capability was needed to perform several iterations of data analysis.
- **Large datasets:** With more than 450 locations and 200,000 items in their item master (as of 2004), the number of item-location combinations and sales transactions for each of those combinations was humongous. Any proposed

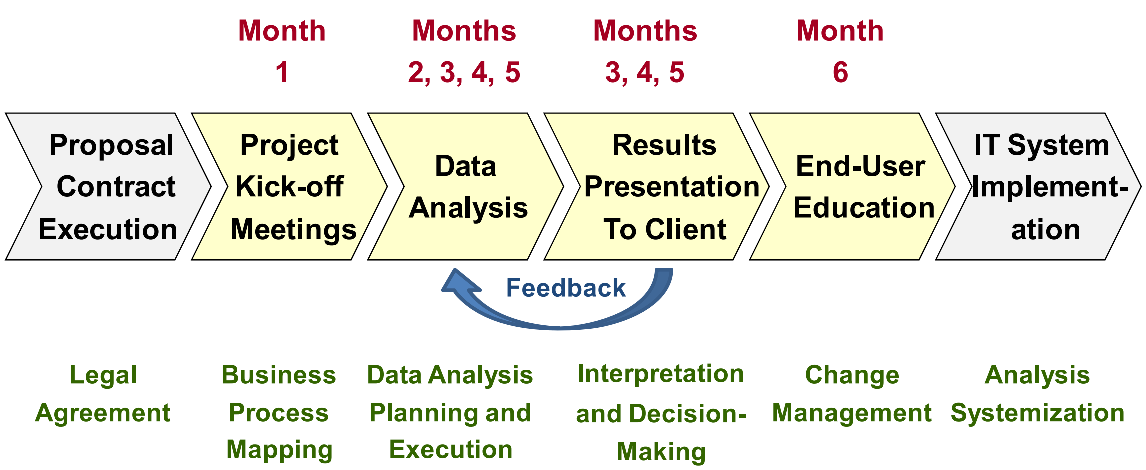
automation tool clearly needed to have the muscle power to handle millions of transactional data records.

- **User changeable criteria:** Similar to the repetitive analysis runs as stated above, several "what-if" scenario runs were also expected wherein the various model criteria and parameters need to be easily manipulated by the end-user.

3.1 Data Analysis in a Typical Project Life Cycle

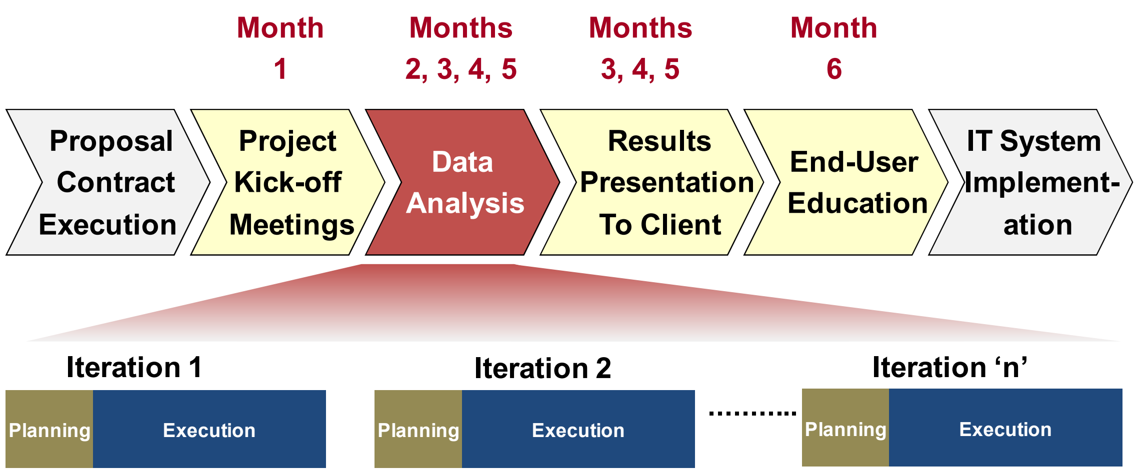
A typical project on inventory management (or any other similar data analysis oriented project) spans about 6 to 10 months depending upon the company size and business complexity. This is based on a multi-tasking environment where both the company and SCSL engage in various activities / initiatives other than just work at a stretch on one given project. It can be seen from Figure 3.1 that a significant amount of time and effort is associated with data analysis related tasks.

Figure 3.1 Typical Project Life Cycle Overview



A closer look at the data analysis process and its components revealed that a significant amount of time and effort was taken up for data analysis "execution" (compared to "planning") as shown in Figure 3.2. When considering the fact that there are typically several iterations of data analysis in a single project, this has a compounding effect on the overall project timeline and resources. The main reason for the long time taken for execution was due to the *lack of standardized data processing procedures* and technology tools used for the purpose. Most of the work was being done in spreadsheets in an ad-hoc way. For instance, in a given project each iteration of data analysis would require an almost entire repetition of the previous iteration's work even if it was for the same company.

Figure 3.2 Repetitive Nature of Data Analysis Execution

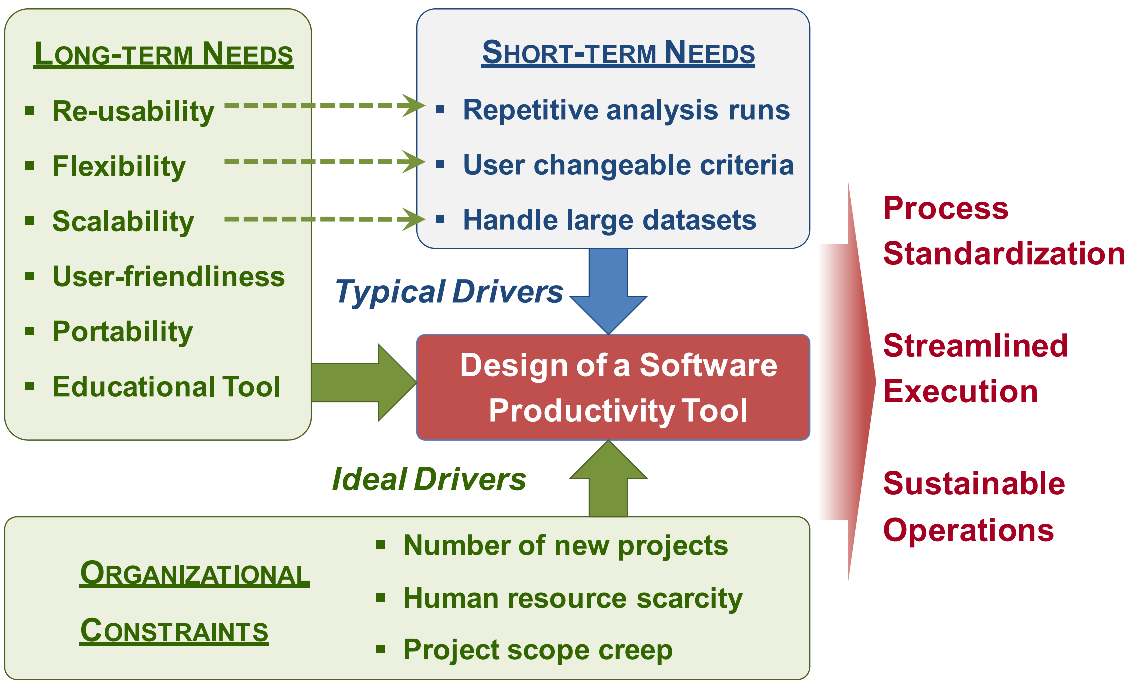


Ideally, more time and resources need to be spent on value-adding activities such as results interpretation, what-if analysis, presentation preparation, communication with client, and knowledge dissemination. So, the idea was to significantly reduce the time and effort required for data analysis "execution" in order to re-allocate time and resources for "planning" related activities.

3.2 A Comprehensive Framework of Productivity Needs

It was indeed not going to be practical to perform the data analysis tasks for the Wilson project using brute force as was done earlier (even accounting for just the short-term requirements mentioned above) due to the scale of the project. Hence, accounting for both the immediate and long-term requirements a holistic framework of productivity needs and automation was developed as illustrated in Figure 3.3.

Figure 3.3 A Comprehensive Framework of Productivity Needs



In most situations, short-term needs drive the design and development of a software application. But it can be seen from Figure 3.3 that the long-term needs actually encompassed the short-term needs. This provided the motivation to pursue the long-term goals but incrementally. The ultimate benefit would be a sustainable operations model for SCSL that does not require heroics to meet project deadlines and deliverables.

As with any initiative, ROI had to be considered for incorporating long-term needs into the design and development of the proposed productivity solution since relatively more time and effort was going to be involved. The concern was to ensure long-term ROI by re-using the tool and/or parts of it in future. But the justification clearly came from the organizational constraints (as shown in Figure 3.3) like the number of similar new projects in the pipeline, lack of human resources (more about this is discussed in section 5), and project scope creeps that resulted in more than expected workload.

3.3 Design of a Software Productivity Tool

3.3.1 Choice of Appropriate Technology

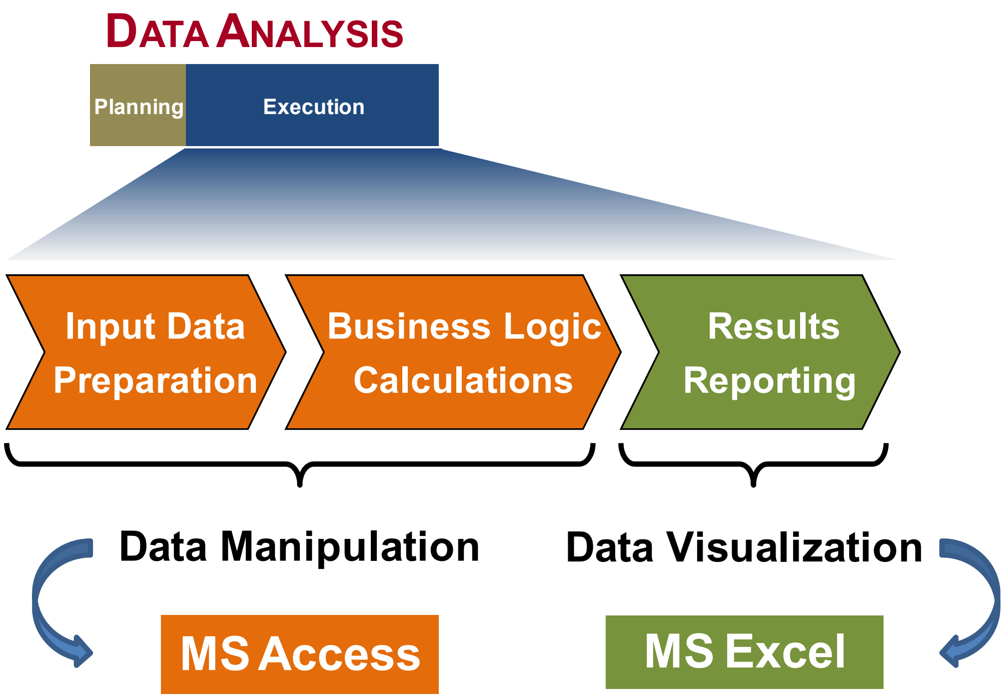
Many earlier SCSL projects and their execution approach had clearly demonstrated the long-term operational impact of choosing a certain technology platform for a given application. For example, for a project related to truck loading optimization and visualization MATLAB was used just because the developer was more comfortable with it rather than accounting for critical needs such as long-term code maintenance, licensing issues when the client decides to implement in real-time, and scalability and portability of the application (such as provided by Java 3D for the same scenario).

The capabilities and limitations of information technology tools available in the market and more importantly their applicability in a certain environment are often not thoroughly investigated to make a well-informed decision. The lack of effectiveness during the beginning stages of an application design usually cannot be made up with raw efficiency later on and eventually the application gets re-done completely from scratch.

Keeping the above issues in mind, the data analysis execution processes were examined in detail to determine the appropriate technology platform to build the application on. Figure 3.4 depicts the three major components of data analysis execution namely Input

Data Preparation, Business Logic Execution, and Results Reporting. The first two components mainly involve heavy *data manipulation* and the last one involves *data visualization*.

Figure 3.4 Data Analysis Execution Processes and Choice of Technology



Spreadsheets, knowingly or unknowingly, often are used as the panacea to perform all of the three major data execution processes whereas they are well suited for mainly reporting and visualization purposes. On the other hand, relational databases are primarily meant to handle data manipulations and are far better at that. MS Access was an excellent choice for SCSL requirements since it is in fact a special application offering much more than classic database features. MS Access and Excel also satisfied other needs such as relatively easy programming for quick application development, broad availability and familiarity of application with end-users and programmers alike.

3.3.2 Programming Highlights

The following four features capture the essence of the programming efforts related to the design and development of the productivity tool and relevant highlights are given below:

- Modularity.
- Abstraction.
- Documentation.
- Coding Efficiency.

It was important to maintain *modularity* during the design and development of the productivity tool since things had to be done in an incremental fashion. For instance, the Wilson project involved all three major inventory processes – Stratification, Forecasting, and Replenishment in that order – but the deliverables were time-phased. So, while the initial project focus would be on Stratification, the rest would soon follow which meant that SCSL had to be equipped with the corresponding tools in a timely manner.

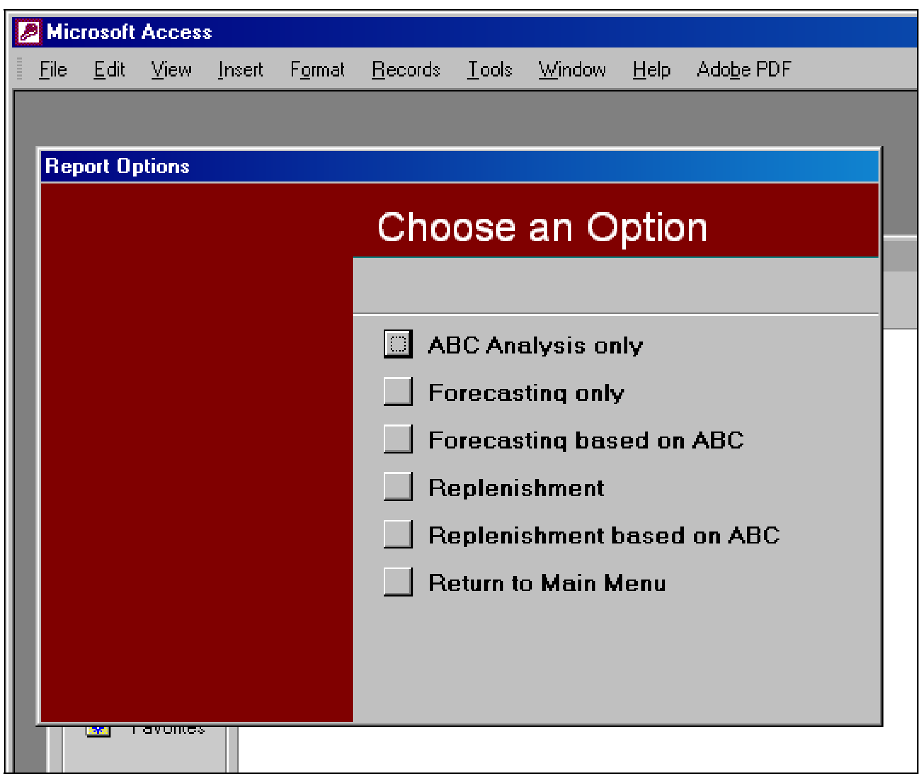
This translated operationally into building the software tool in *incremental layers* without the need to later perturb or undo the initial layers if not leverage them. Table 3.1 shows the possible combinations of using the three major modules independent of each other except in the case of Replenishment analysis which requires Forecasting results as a mandatory input and hence was locked in with it.

Figure 3.5 is a screenshot of the tool's main menu that illustrates the implementation of the incremental layers concept wherein depending upon the choice of the analysis scenario, the subsequent user form would dynamically change without causing any major disruption to the form elements since by design they are common to all the modules. A more detailed screenshot is given in APPENDIX A.

Table 3.1 Various Scenarios of Using Analysis Modules

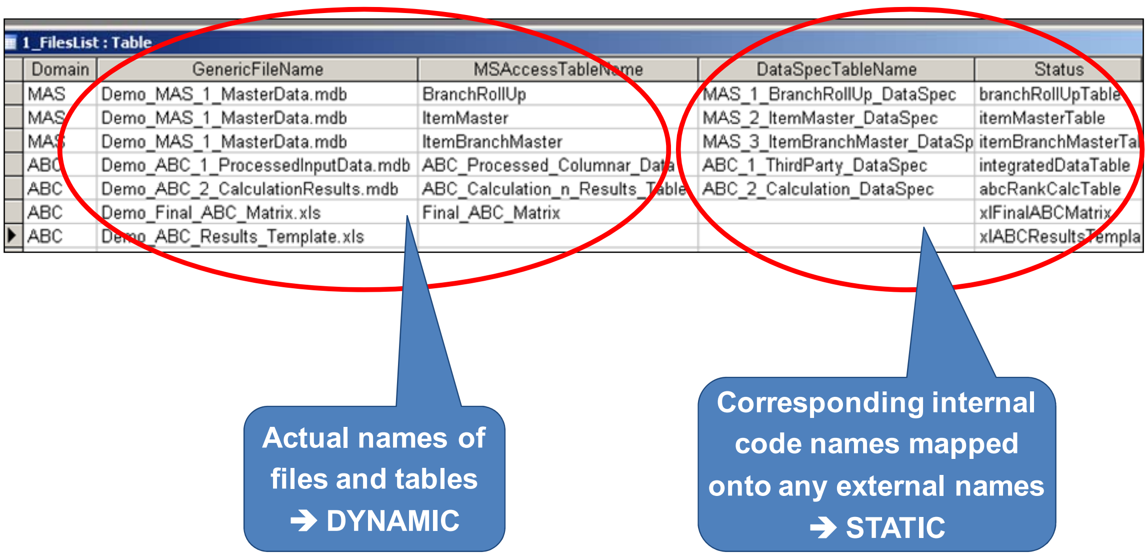
Scenario	Stratification Module	Forecasting Module	Replenishment Module
1. Stratification analysis only	Yes	-	-
2. Forecasting analysis only	-	Yes	-
3. Both Stratification and Forecasting analysis	Yes	Yes	-
4. Replenishment analysis only (dependent on Forecasting results)	-	Yes	Yes
5. Perform all 3 analysis	Yes	Yes	Yes

Figure 3.5 Modular Analysis Reporting Options



Following *abstraction* is a good programming practice and plays a key role in determining flexibility of the application when used in real time. The concept of *metadata* (data about data) was leveraged heavily to abstract the names of data fields, tables, files, and folders so that setup times are minimized when customizing the tool for several companies. Figure 3.6 illustrates how the internal code names used within the core modules were mapped onto external names that could be changed without affecting the program flow. Many repetitive functions were abstracted into generic sub-routines and all major user input criteria (such as ranking rules and data filters) were parameterized as global variables.

Figure 3.6 Illustration of Metadata Concept


1_FilesList : Table

Domain	GenericFileName	MSAccessTableName	DataSpecTableName	Status
MAS	Demo_MAS_1_MasterData.mdb	BranchRollUp	MAS_1_BranchRollUp_DataSpec	branchRollUpTable
MAS	Demo_MAS_1_MasterData.mdb	ItemMaster	MAS_2_ItemMaster_DataSpec	itemMasterTable
MAS	Demo_MAS_1_MasterData.mdb	ItemBranchMaster	MAS_3_ItemBranchMaster_DataSp	itemBranchMasterTa
ABC	Demo_ABC_1_ProcessedInputData.mdb	ABC_Processed_Columnar_Data	ABC_1_ThirdParty_DataSpec	integratedDataTable
ABC	Demo_ABC_2_CalculationResults.mdb	ABC_Calculation_n_Results_Table	ABC_2_Calculation_DataSpec	abcRankCalcTable
ABC	Demo_Final_ABC_Matrix.xls	Final_ABC_Matrix		xlFinalABCMatrix
ABC	Demo_ABC_Results_Template.xls			xlABCResultsTempla

With a constantly evolving tool, maintaining a full-fledged *documentation* was itself a significant task but it was critical for future references even for the developer. So, in order to strike a balance much of the documentation was embedded within the code itself. Also, basic naming conventions were followed to ensure they act as good surrogates for detailed documentation. Refer APPENDIX A for relevant screenshots.

Coding efficiency is an integral part of any software application development and the productivity tool was no exception. A few relevant points are listed below:

- Automatic folder path assignment to a user's current location of files.
- Clear delineation between public and private variables.
- Custom defined tables and fields leading to file size reduction.
- Program code present only in the control center database.

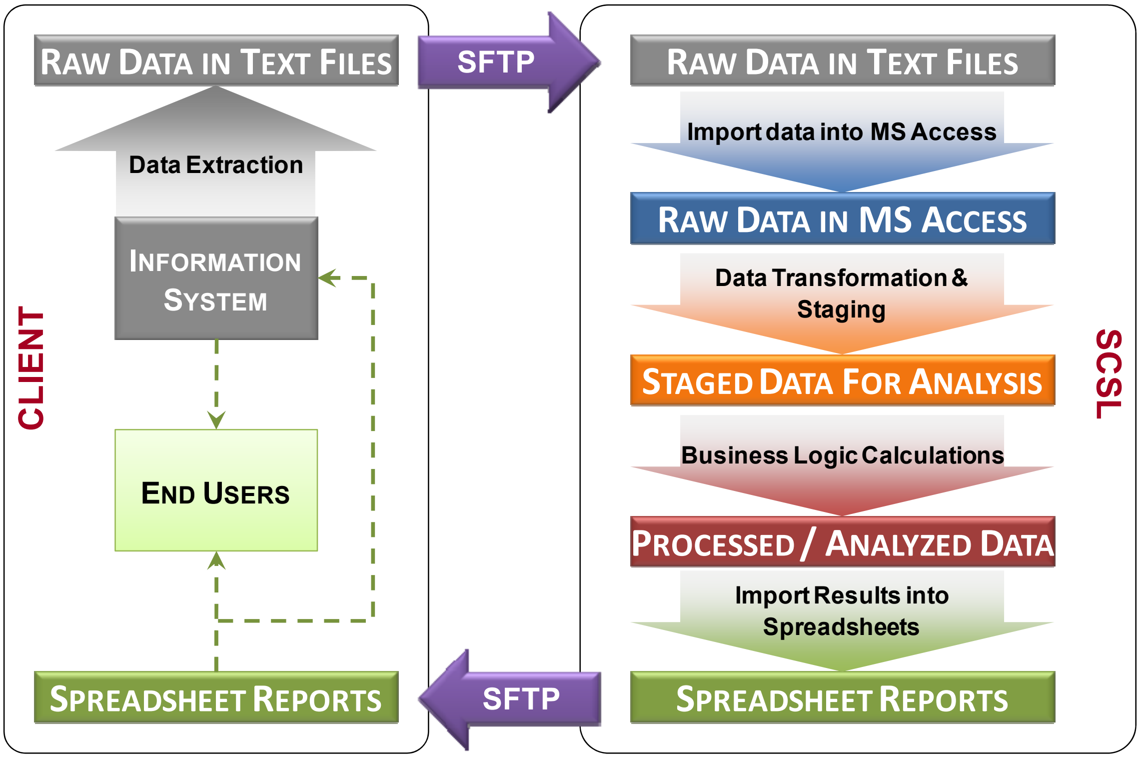
3.3.3 Software Tool Architecture Overview

The productivity tool was based on a combination of MS Access and Excel files with almost all of the major functionalities embedded within MS Access. As mentioned earlier, MS Excel was mainly used for storing some analysis criteria and for reporting the final analysis results in the form of charts and summarized views. The following are the key features / capabilities of the tool from a software architectural standpoint:

- Centralized control of data files.
- Dynamic population of data filter elements.
- Seamless integration of analysis criteria in MS Access and Excel files.
- On-demand creation of output tables as per dynamic data filters.
- Quick run-time / execution capability.

Figure 3.7 provides a high-level overview of the software tool architecture and flow of data and results when the final version of the tool was completed.

Figure 3.7 Overview of Software Tool Architecture and Data Flow



3.4 Process Standardization

The core algorithms or engines were standardized within the software tool in such a way that no human intervention would be necessary unless there was an intentional change required. But this was not the case with feeding the input data into the tool and reporting results since every company's data was unique and hence required a few one-time setup procedures. The best that could be done in this case was semi-automation striving to minimize expected human effort. In this respect, many data handling processes were standardized but without compromising on flexibility.

3.4.1 Standardized and Flexible Input Data Templates

In the early going, SCSL's data requests from clients were ad-hoc and sometimes the format requirements were rigid that could potentially cause inconvenience to the client. One of the key developments during the automation exercise was a better understanding of *master (relatively static)* versus *transactional (dynamic)* data. All data requirements were fitted into these two generic categories which made it easy for clients since IT systems are in fact based on this fundamental concept of data. An example of this with respect to Inventory Stratification analysis is shown in Table 3.2 below.

Table 3.2 Master vs. Transactional Data for Inventory Stratification

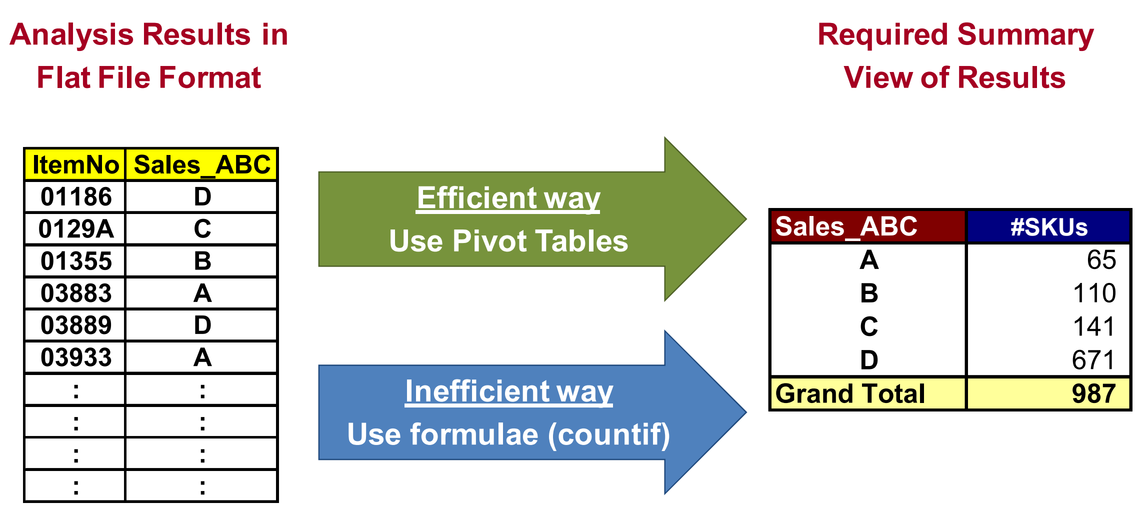
Master data	Transactional data
Location Master ▪ Organizational rollup structure **Item Master** ▪ Item attributes common at a corporate level **Item-Location Master** ▪ Item attributes specific at a location level, if any	**Sales Transactions** ▪ At a detailed level (ex: Order Line No. level) **Inventory Levels** ▪ Monthly Ending / Average inventory data at a Location-Item level

Although the input data requirement templates were standardized mainly for internal purposes, enough flexibility was provided to clients. For example, if Item Master data was not available, then it was derived from Item–Location Master or from the transactional data itself. The Location Master data may be huge and complex for a company with hundreds of locations but for small and mid-sized companies it could be manually created with ease if not available. File format restrictions (such as .txt or .csv) were relaxed since MS Access could handle most available file formats. For an overview generic data requirements used as a starting point in projects refer to APPENDIX B.

3.4.2 Re-discovery of Pivot Tables for Data Summarization

Pivot tables and charts in spreadsheet applications like MS Excel is perhaps the most underestimated yet very powerful feature when it comes to reporting data analysis results. It is a common requirement to summarize the output / results of a model in various ways in order to make the information useful for decision-making purposes from a business viewpoint. Figure 3.8 illustrates a scenario where a particular required summary of results from a stratification analysis can be achieved in two ways although using pivot tables compared to manually created formulas is much more efficient. Some of the default pivot table reports and associated graphs used in inventory stratification projects are provided in APPENDIX B.

Figure 3.8 Data Summarization Techniques

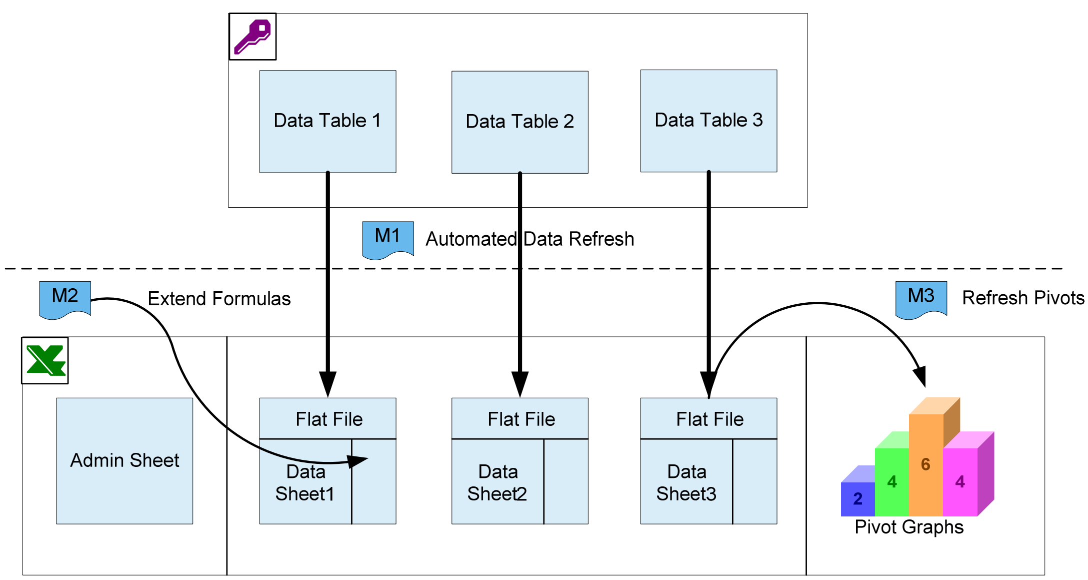


Significant man-hour savings were achieved by adopting the pivot tables feature in all of the results reporting activities. This was especially helpful when clients expressed interest in slicing and dicing analysis results in various ways for intelligent decision-making. Pivot tables enabled an easy and efficient way of summarizing and manipulating analysis results by many orders of magnitude.

3.4.3 Standardized and Customizable Report Templates

Basic result reports and layouts were developed using MS Excel spreadsheets and were made into generic "templates" that could be re-used in multiple projects. These templates would be the default reports unless a project required more customized reports which were also easily achievable using pivot tables as mentioned above. There were three major steps in the results reporting process namely (1) importing results from MS Access to Excel, (2) potential new calculations using Excel formulas, and (3) refreshing pivot data. All these steps were automated and Figure 3.9 gives an overview of it.

Figure 3.9 Data Refresh Steps in MS Excel Results Template



3.5 Salient Tool Features and Benefits

3.5.1 Re-usability

One of the major intentions of the productivity tool was to set a trend of leveraging and maximizing the benefit of an individual's work output even after he / she leaves the organization. This is a common problem in knowledge organizations and turns out to be quite costly in a HR constrained environment. Table 3.3 shows a list of projects from 2004 that fully or partially leveraged the productivity tool.

Table 3.3 Projects That Leveraged on the Productivity Tool

FY 2005	FY 2006	FY 2007	FY 2008	FY 2009
▪ Wilson ▪ Johnstone (12 mini projects) ▪ Womack ▪ CHBriggs ▪ Webb ▪ BakerHughes ▪ DealerTire	▪ National Sales ▪ TKMNA ▪ ISCBM	▪ Pricing consortium (multiple projects)	▪ Smith ▪ Spartan Stores	▪ Brenntag LA ▪ DWD

Assuming a scenario of a typical six-month company project consisting of three major iterations of data analysis with the following specifications, Table 3.4 below gives a break-up of typical man-hours necessary to perform the data analysis work based on ad-hoc procedures as opposed to using an automated tool.

- 10 sales locations.
- 30,000 item-location combinations.
- 360,000 records of one year monthly inventory levels for the given 30000 item-location combinations.
- 500,000 sales transactions for one year.

Table 3.4 Man-hours for Ad-hoc vs. Automated Procedure

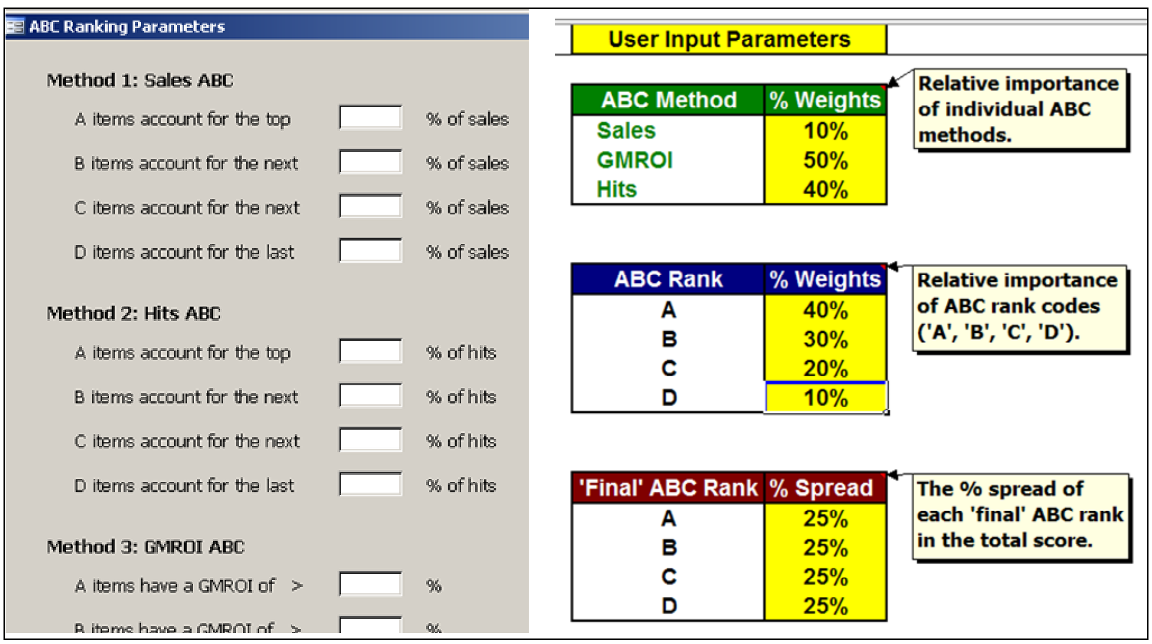
Data Execution Activity	Man-hours based on ad-hoc procedures			Man-hours based on automated tool		
	Iter 1	Iter 2	Iter 3	Iter 1	Iter 2	Iter 3
Input data preparation	20	15	15	5	1	1
Business logic calculations	25	15	10	0.5	0.5	0.5
Results reporting	20	15	10	5	0.5	0.5

In the above scenario, the total number of man-hour savings corresponds to around 130 hours. Assuming a typical industry blended hourly rate of $200 per hour, the saving equates to more than $25,000. Now, applying this logic for all the projects listed in the table above, the total savings amount to would run into several hundred thousand dollars. Obviously this is a rough-cut projection since each project is unique in its own way nevertheless the productivity tool had a profound impact on operational workload.

3.5.2 Flexibility

The abstraction of key analysis parameters / criteria as user input variables available on the tool's front end provided an opportunity to perform what-if analyses quickly and easily. It can be seen from Figure 3.10 that certain analysis criteria were maintained in MS Excel so that multiple criteria sets could be easily saved out and swapped whenever required. MS Access files get bloated when data is cleared and populated on a repeated basis. So, a "tool maintenance" option was given to the end-user which would compact and repair relevant database files.

Figure 3.10 Flexible User Input Forms



3.5.3 Scalability

During the design and development of the tool in 2004 - 2005, MS Access 2003 was the platform used which was capable of handling file sizes up to 2 Gigabytes (GB) without any major issues (assuming standard PC configurations). As stated earlier, Wilson dataset was one of the biggest in SCSL's history and the tool could easily handle the largest of Wilson data files that was around 300 Megabytes (MB). This meant that the tool was well capable of handling datasets of small and mid-sized companies that would be comparably much smaller and was also independent of the increase or decrease in volume of master and transactional data for a given set of specifications. For example, an increase in the number of locations or product lines would require no change to the tool.

3.5.4 User-friendliness

The tool was really intended to be used internally within SCSL which meant that the typical users would be programmer analysts who would be given full access to the code and other settings. A new analyst trying to customize the tool for a company was required to understand mainly the back-end of user input forms and not the entire program since much of the code was abstracted and made foolproof. And as mentioned earlier, inline documentation and proper naming conventions combined with a quick walk-through of the tool provided sufficient guidance.

3.5.5 Portability and Bolt-on Capability

In many situations, companies would like to get a copy of SCSL's internal productivity tool to do some analysis on their own. This is easily achieved since the entire tool is based on just two applications MS Access and Excel that are ubiquitous in the enterprise world. So, the lack of licensing issues combined with its user-friendliness made the tool completely portable across multiple computers.

A more rigorous version of the above scenario is when companies need the tool to be deployed live in their IT system network as a bolt-on software solution. This too was possible after enabling an automated download of the required input data from the company's IT system into the tool. Similarly, the results from the tool could then be directly uploaded onto the IT system.

3.5.6 Educational and Marketing Tool

The productivity tool's on-demand capability was useful in educating several data analysis related issues and as a marketing aid when communicating with new clients. This feature was also extremely handy during executive meetings when managers would want to immediately see the results of one or more what-if scenarios. Before the creation of the productivity tool, such requests usually took two to three days turn-around.

4. INVENTORY AND INFORMATION MANAGEMENT IN PRACTICE

Inventory management is largely an information exercise when looked at from a planning standpoint especially for distributors (compared to execution functions like storing and shipping). So for the business community, it would mean that the unprecedented growth and accessibility of computational power in the recent years and the advent of super scale inventory optimization models (*AberdeenGroup Market Alert* 2005) must have made inventory and information management easier given that this was not possible a few years ago. Unfortunately this is not the case for several reasons.

It is only appropriate for IT providers to incorporate cutting edge theoretical research work and offer to the industry for their immediate benefit. This, however, assumes that the latest theoretical models account for at least the majority of real-world business conditions. In fact, Tiwari and Gavirneni (2007) point out a widening gap between academics and practitioners working on inventory control problems. This can be said true of even old theoretical models since companies that run on legacy systems actually use them knowingly or unknowingly but the net effect is still a lack of system compliance with the ground reality.

Hadley and Whitin (1964) predicted difficulties with practical application of inventory theory even when it advances due to lack of proper data, qualified personnel, and compatibility between theory and real-world characteristics. They emphasized a continuing need to adjust theoretical models according to different circumstances and acknowledge the extreme difficulty in doing it. The business world is a complex mesh of interrelated processes and consists of hundreds and thousands of variables that determine the final outcome of an intended plan. For these reasons, Tiwari and Gavirneni (2007) say that "inventory researchers from academia invited into companies to improve inventory performance would need skills beyond theoretical inventory modeling to succeed" and that "the solution almost certainly does not involve applying sophisticated inventory models".

Irrespective of the inventory models used, the quality of data determines the quality of results and subsequent decision-making since garbage-in is simply garbage-out. Quinn (2005) in his interview with Harvard Professor Ananth Raman finds that the quality of data is a real Achilles' heel in the supply chain since usually it is taken for granted and company management does not pay due attention to it. Also, anecdotal evidence shows that there is a general lack of inclination for companies to rigorously test the quality of data. In this regard, Samuelson (2005) says that "no plan of analysis ever survives the first contact with the data".

An overview of practical implementation challenges of inventory management theory was given in the second section. This section focuses particularly on business complexity and data quality issues, their implications on data and algorithm specifications, and certain adaptations / extensions of the theoretical methodologies.

4.1 Real-world Factors Influencing Data Analysis and Decision-making

The effectiveness of a data analysis activity depends on the business relevance and quality of specifications that govern it. The previous section provided a high level overview of the data analysis process in a typical project life cycle and expanded on the "execution" phase. This section is focused on the "planning" phase and the important real-world factors that influence it. There are three major components to the planning phase namely Business Logic Specifications, Data Specifications, and Results Specifications that correspond to Business Logic Calculation, Input Data Preparation, and Results Reporting respectively in the execution phase.

In applied research projects, particularly those sponsored by companies, significant real-world factors need to be taken into account since they profoundly affect the analysis specifications, integrity of data, and ultimately the interpretation and business applicability of the results. Several key practical implementation challenges were listed in section two of which the following factors will be covered in detail here:

- Location, Product, and Transactional attributes.
- Overarching business factors.
- Data integrity issues.

Figure 4.1 Real-world Factors Influencing Data Analysis

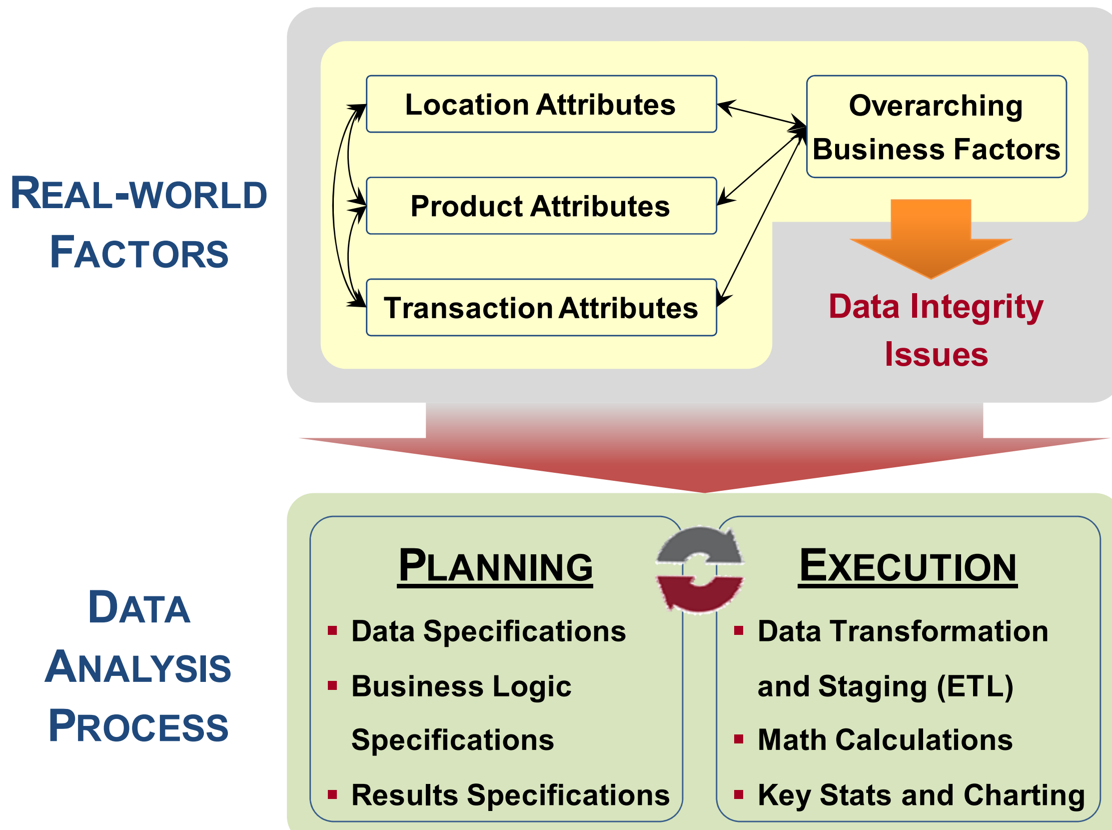


Figure 4.1 shows a framework of how real-world operational factors influence the data analysis process. Given the large number of parameters / variables under each of the influencing factor and the *complex interaction* among the variables, there is a *multiplicative effect* to this entire process that has a significant impact on the interpretation of analysis results and subsequent business decisions. Some of the potential dire consequences of this matrix of inter-related factors are as follows:

- Incorrect actions based on wrong results.
- Unclear cause and effect relationship.
- Increase in exception handling.
- Loss of trust in the IT system defeating the very purpose of systemizing analyses.

Table 4.1 lists some of the key parameters under each of the influencing factors mentioned above. The data integrity issues vary according to the type of analysis and are covered in the forthcoming sub-sections as appropriate.

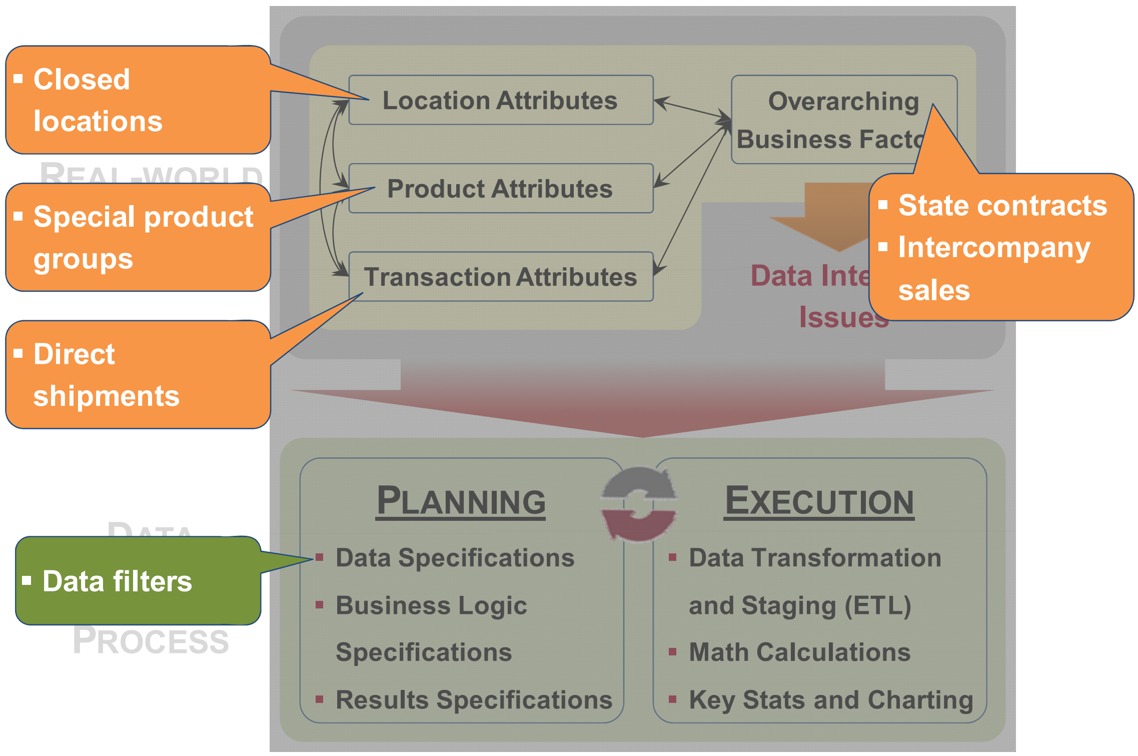
Table 4.1 Sample Parameters of Data Analysis Influencing Factors

Location attributes	Product attributes	Transactional attributes	Overarching business factors

▪ Location type
  ▪ Sales branch
  ▪ DC
  ▪ Hybrid
  ▪ Logical
▪ Roll-up structure
▪ Internal supply allocation
	▪ Stock status
	▪ Product group
	▪ Finished good vs. component
	▪ Warranty status
	▪ Product life cycle
	▪ Unit cost
	▪ Supply source
		▪ Transaction date
		▪ Discounts / Rebates
		▪ Returns
		▪ Backorders
		▪ Delivery modes
		▪ Multiple shipments
		▪ Unit of measure
			▪ Industry type
			▪ Promotions / Exceptional SOs
			▪ Donations
			▪ State contracts
			▪ Intercompany sales
			▪ Costing policies

Figure 4.2 depicts an example of how some business parameters under each influencing factor lead to defining data filters during the data analysis planning phase in order to properly identify data that needs to be included (and excluded). Refer to APPENDIX C for similar examples.

Figure 4.2 Example of Business Parameters Affecting Data Analysis Planning



4.2 Inventory Stratification Analysis

As noted in section two, inventory stratification for most distributors is primarily a housekeeping process that involves reduction of excess inventory and/or redeployment of low ranked inventory into the critical category with a final objective of increasing a company's ROI. So, a stratification methodology that is directly based on or derived off of the ROI formulation would serve the purpose. But two other criteria that cannot be ignored for a distributor are sales dollars and velocity of movement. Hence, SCSL's inventory stratification framework for distributors included the following three methods:

- **GMROII** (Gross Margin Return on Inventory Investment): The ROI logic applied for inventory in terms of dollars.
- **Sales:** Volume of sales in terms of dollars.
- **Hits:** Velocity or frequency of inventory movement (fast vs. slow move).

For the above three methods, a default set of ranking rules and parameters as listed in Table 4.2 were followed but they were indeed customized depending upon the business environment. For example, for the GMROII method a company's total GMROII could be calculated and used as the base to set criteria for each ranking category rather than using standard industry benchmarks. It can also be noticed that the Sales and Hits methods follow a typical 80:20 / Pareto rule (*relative*) whereas the GMROII method is based on a ratio (*absolute*) which makes a difference while interpreting analysis results.

Table 4.2 Default Ranking Rules and Criteria for Stratification Methods

Rank Category	Stratification Methods and Rank Criteria		
	GMROII	Sales ($)	Hits
A	GMROII >= 300%	Top 60%	Top 60%
B	GMROII >= 200% and < 300%	Next 20%	Next 20%
C	GMROII >= 100% and < 200%	Next 10%	Next 10%
D	GMROII < 100%	Next 10%	Next 10%
X	Zero Inventory and GM > $0	-	-
Y	Zero Inventory and GM <= $0	-	-

The following sub-sections discuss about the salient points discovered and addressed during the internship with respect to the above stratification methods when attempting to implement them for SCSL clients.

4.2.1 Revisiting Sales Quantity Based Ranking

Inventory ranking based on sales activity is a widespread practice in industry and is offered by almost all information systems as a standard feature. But one of the common pitfalls observed with this methodology is the use of sales "quantity" as the base data for relative ranking. This is appropriate as far as the units of measure are the same for all of a company's products in inventory. Although this may be true for certain business channels, it is rarely the case in general since industrial products come in various sizes and shapes.

Figure 4.3 Impact of Units of Measure on 80:20 Rule-based Ranking

Item No.	Item Description	Product Family	Stocking UoM	Total Qty Sold
FL07X	5" 25 FT FLX VER4.5	SHEET METAL	BG	32
FL207EXVNY	BLUE BUTYL FLEX - 6" x 21'	SHEET METAL	BG	51
065380K	TWIST BELT BOX - 10'	SPECIAL ORDERS	BX	120
35003121MB	BLOWER 5/4HP S3P MOTOR	MOTORS	EA	12
595024UIR7	CONDENSER ASSEMBLY	REFRIGERATION	EA	9
74190H	10' PIPE COLOR	PIPES	EA	700
94J76KL	1/4" BUSH & CLAMP	SHEET METAL	EA	1024
CON4111	SPHERICAL - 3600 CPM	SPECIAL ORDERS	EA	3
TR66991	DRAIN ADAPTER	CABINETS	EA	45
1514P0	INSULATED FLEX - 4"	SHEET METAL	FT	5012
35202VV	35/2 VV THERMOSTAT WIRE	ELECTRIC	FT	25580
PVC84	PVC - 6" x 30' PIPE	PIPES	FT	42900
S0421	5" FLEXIBLE SHEET	SHEET METAL	FT	18421
4C9031	SPACER RING ALLOYED	MOTORS	PKG	91
DM80G	GASKET ROLL - DUCTILE	SPECIAL ORDERS	RL	9012
SO0OD	PC CORD ROLL OF 50'	ELECTRIC	RL	590
1948GAL	4" x 10' PAINT GAUGE	SHEET METAL	SH	63
LRE8534	34 x 48 x 12 MEDIUM CD/BCS23	PADS	ST	761

If typical 80-20 ABC rule is applied for 'qty' sold, then items with UoM of 'FT' will get ranked higher.

Figure 4.3 shows a real-world example of a group of products having different units of measures and it can be seen that when they are ranked relative to each other, those with "feet" unit of measure having large quantity figures associated with them would invariably get a higher rank. But this may not reflect business reality and in general does not account for different characteristics of products. On the other hand, sales "dollars" represents a common unit of measure for all products irrespective of business environment and hence that methodology was adopted.

4.2.2 Multi-criteria Ranking

Multiple ranking methods lead to information overload for end-users particularly those on the firing line who are required to make quick decisions on competing business goals. This was clearly evident during implementation of SCSL's stratification methods where situations, for instance, could involve products with a lower GMROII rank but higher Sales and Hits rank or vice versa.

Table 4.3 GPR Calculation Example for Multi-criteria Ranking

Course name [Stratification method]	Grade [Rank]	No. of credit hours [Weight]	Grade points [Weighted score]
INEN 101 [GMROII]	A	4	16
INEN 102 [Sales]	B	3	9
INEN 103 [Hits]	A	3	12
	Total	10	37
	Grade Point Ratio [Final score]	3.7	

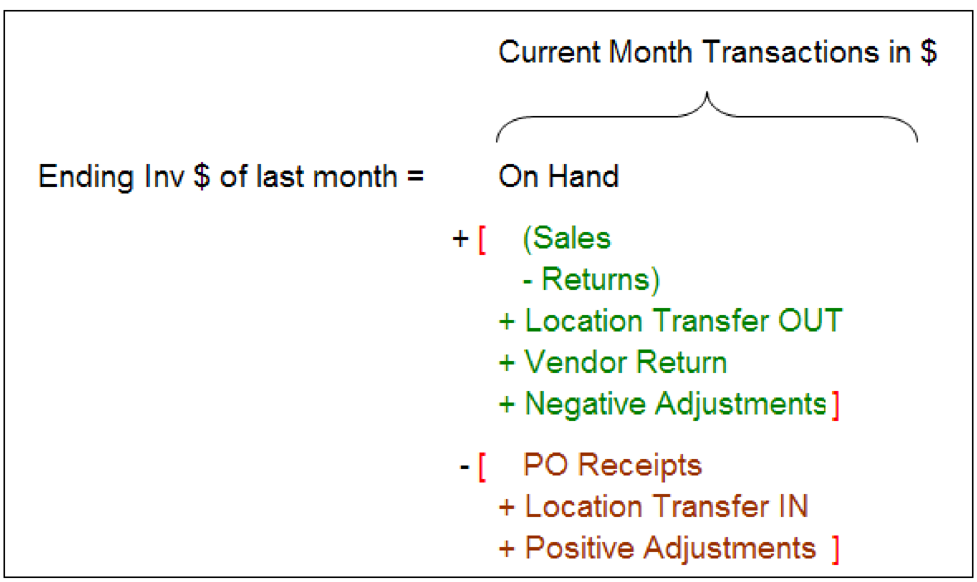
So, in order to strike a balance, the output of the three ranking methods had to be appropriately synthesized into a single rank without losing sight of the overall business objective. For this purpose, a scoring system inspired by the GPR calculation process in Universities was developed. Table 4.3 shows how a typical GPR calculation logic for a three-course semester applies to combining the three stratification methods leading to a final score that can eventually be converted back to a final rank category.

4.2.3 The Conundrum of Average Inventory Calculation

One of the seemingly simple but perhaps quite a challenging issue in inventory related analysis is the calculation of average inventory levels. Some of the key relevant points that surface during implementation are listed below:

- Availability of historical average inventory data.
- Impact of missing data points and data aggregation procedure.
- Impact of costing policies.

Figure 4.4 Backtracking Ending Inventory



In many projects, it was shocking to find out that historical average inventory data was *simply not available* in clients' information systems. Given that this was a critical piece of information for data analysis, alternate solutions had to be developed. Figure 4.4 shows one such example where historical month-end inventory levels were backtracked from transactional data. But this was usually an extensive data exercise prone to errors due to several potential exceptions in transactional data.

Another critical issue on this topic is the calculation and interpretation of various *levels* of average inventory information. There are two interrelated factors to this issue:

- Treatment of missing data points as either zeros or nulls.
- Method of data aggregation across various dimensions like time, location, etc.

This is best explained with an example. Figure 4.5 shows a snapshot of inventory on-hand values for a product at a location taken at the end of each week over a period of six months. The objective is to arrive at an overall inventory average for this product based on the given information. Both the given scenarios first aggregate the weekly on-hand values to get a monthly average which in turn is averaged to get the final overall inventory average. A discrepancy of around $25 can be noticed between the two methods which is caused by different ways of treating the missing data points. The top scenario shows an averaging technique based on only the available data points whereas the bottom scenario substitutes zero for the missing data points. This leads to a higher average inventory figure for the top scenario and a lower one for the bottom scenario.

This example of a single product shows just one dimension (time, although at two levels weekly and monthly) that was collapsed to get the overall inventory average. When more dimensions such as locations, products, and customers are involved the discrepancy balloons.

Figure 4.5 Impact of Missing Data Points and Aggregation Procedure

Scenario	Fiscal Week	Fiscal Month						
		Jan 05	Feb 05	Mar 05	Apr 05	May 05	Jun 05	
Ignoring null value weeks	W1	26.78	160.68		133.9	53.56	107.12	
	W2		133.9		26.78	26.78	187.46	
	W3		133.9	160.68			133.9	
	W4	80.34	80.34	160.68	107.12	53.56	133.9	Avg of Monthly Avg
	W5	80.34						
	Monthly Avg	62.49	127.21	160.68	89.27	44.63	140.60	104.14
Substituting zero for null value weeks	W1	26.78	160.68	0	133.9	53.56	107.12	
	W2	0	133.9	0	26.78	26.78	187.46	
	W3	0	133.9	160.68	0	0	133.9	
	W4	80.34	80.34	160.68	107.12	53.56	133.9	
	W5	80.34				0		
	Monthly Avg	37.49	127.21	80.34	66.95	26.78	140.60	79.89

Several factors that play a role in determining the appropriate way to calculate average inventory levels are given below:

- **Information system procedure:** Null or zero for missing data points.
- **Frequency of data capture:** Daily, weekly, or monthly inventory snapshots.
- **Inventory movement:** Slow vs. rapid (lumber yards vs. high-tech industry).
- **Product life cycle:** New, obsolete, steady-state, or seasonal / intermittent.
- **Overall analysis timeline:** Short vs. long (oil industry vs. building materials).

Normally, this issue is not given enough attention due to the assumption that the discrepancies would perhaps be negligible whereas real-world examples show that this is not the case. As an example, for one company it was required to calculate GMROII for many of their key customers which in turn needed average inventory information at a customer level. Table 4.4 shows the average inventory levels for some of the company's key customers according to different calculation approaches. It can be seen that the discrepancies were rather large and hence had a major impact on results interpretation.

Table 4.4 Discrepancy of Average Inventory Values

Customer name	Scenario 1 – Missing data points treated as zero		Scenario 2 – Missing data points ignored	
	Average inventory ($)	GMROII	Average inventory ($)	GMROII
Customer 1	$ 4,562,305	169%	$ 6,189,977	128%
Customer 2	$ 6,590,354	193%	$ 10,116,126	141%
Customer 3	$ 23,592,533	173%	$ 30,056,768	149%
Customer 4	$ 11,382,117	87%	$ 17,294,031	59%
Customer 5	$ 3,454,848	24%	$ 5,464,325	16%

Apart from the above issues, *inventory costing policies* have an impact on average inventory levels when calculated in terms of dollars. Typically, companies follow one of the standard costing policies like First In First Out (FIFO), Last In First Out (LIFO), Average Cost, or Standard Cost. When daily / weekly / monthly inventory level of products is captured in terms of quantity and then multiplied by their corresponding product costs, the costing policy followed by the company can lead to a major discrepancy in the inventory dollar values. This has to be appropriately accounted for in the business logic by fine-tuning the rules and parameters.

4.2.4 Data Integrity Issues

Apart from the above mentioned issues, there were a number of exceptions that surfaced during execution of inventory stratification data analysis which led to refinement of data and business logic specifications which in turn impacted the interpretation of results.

Table 4.5 Data Integrity Issues for Inventory Stratification Analysis

Data integrity issue	Impact on stratification methods		
	GMROII	Sales ($)	Hits
Relative ranking		Yes	Yes
Tie-breakers		Yes	Yes
Negative net sales or hits		Yes	Yes
Very large sales or hits numbers		Yes	Yes
Zero selling price	Yes	Yes	
Negative gross margin	Yes		
Negative average inventory	Yes		
Very low average inventory	Yes		
Insufficient data history	Yes	Yes	Yes

Table 4.5 gives a list of exceptions that were encountered along with their impact on each of the three stratification methods. Figure 4.6 illustrates the "tie-breaker" data integrity issue with sample data. Similar examples are given in APPENDIX C.

Figure 4.6 Impact of Tie-breakers on Sales($) Ranking Method

ItemNo	Product Family	Sales ($)	% of Total Sales	Cumulative Sales %	Rank
SO0OD	PVC	$ 101	20%	20%	A
A42143105	ELEC	$ 99	19%	39%	A
1FA632	ELEC	$ 79	15%	54%	A
ROP84	PVC	$ 79	15%	70%	B
FN0683209	MTL	$ 42	8%	78%	B
S0421	PVC	$ 41	8%	86%	C
350B3A	PVC	$ 34	7%	92%	D
015346EN	PVC	$ 25	5%	97%	D
FL2007EX	DRL	$ 15	3%	100%	D
		$ 515			

> Sorting just by Sales ($) is not enough in this case. Proper tie-breaker criterion required to rank items appropriately.

4.3 Forecasting Analysis

Forecasting related activities during this internship period focused on tasks that would augment the previous work done at SCSL in an extensive forecasting project including math model modifications and error metrics.

The key development in forecasting analysis during the internship period was the concept of demand pattern classification. The classification scheme developed by Eaves (2002) was used as the foundation and was adapted for SCSL purposes.

4.3.1 Demand Pattern Classification

Demand pattern classification is basically a scheme of parameters / identifiers that describe a few key characteristics of customer demand and is mainly used to augment the mathematical forecast models. The models by themselves can handle certain predictable variations (for example, Winter's Triple Exponential Smoothing model accounts for both trend and seasonality) but are not meant to classify demand characteristics such as intermittency and lumpiness.

The classification scheme can thus serve as a guiding framework to selectively apply different types of forecast models based on the underlying demand pattern. For instance, Croston's forecast model is known for its applicability in intermittent demand environments. The scheme consists of three key identifiers and a final index that combines those identifiers. It is listed below and is illustrated in Figure 4.7:

- **Demand Intermittency**: Frequency of usage (similar to 'hits' in stratification).
- **Demand Size**: Quantity of usage.
- **Demand Variability**: Deviation from mean usage.
- **Demand Stability Index**: A single index derived from the above 3 identifiers.

Figure 4.7 Demand Pattern Classification Example

Low Demand Size

Slow Moving (Intermittent demand)

Fast Moving (Non-intermittent)

P1	P2	P3	P4	P5	P6	P7	P8	P9	Stdev / Avg
5	0	0	0	12	0	0	7	0	1.65
11	0	0	0	25	0	0	3	0	1.98
342	0	0	0	312	0	0	275	0	1.51
123	0	0	0	298	0	0	543	0	1.79
3	7	4	11	9	15	6	5	12	0.50
1	15	7	25	14	3	6	18	33	0.78
700	610	820	970	540	1003	333	599	801	0.30
987	143	0	760	302	491	1820	289	580	0.92

High Demand Size

High demand variability (lumpy / erratic)

4.3.2 Overlaying Inventory Stratification Ranks

Inventory stratification is often used to set business policies including decisions on what items to forecast and not to forecast. For instance, C and D items are recommended not to be forecasted due to the presumption that their demand pattern is unpredictable. Given that large number of items fall into the C and D category, it may not be true that all those items are not fit for forecasting.

So, the demand pattern classification scheme was overlaid with inventory stratification ranks to see the distribution of C and D items with stable demand pattern and similarly the distribution of A and B items with unstable demand pattern. This information was later useful to set forecasting rules and make appropriate tactical decisions. Figure 4.8

shows an illustration of this concept and it can be seen that many C and D items do have a stable demand pattern which means that safety stock settings could be controlled more tightly for those set of items.

Figure 4.8 Overlaying Inventory Stratification with Demand Patterns

Count of ItemNo	Final_Demand_Predictability_Index		
ABC Final Class	1_Stable	2_Moderately_Stable	3_Unstable
A	737	75	38
B	2600	476	909
C	1438	371	1668
D	479	405	4827
Grand Total	5254	1327	7442

Many are infact new items

4.3.3 Data Integrity Issues

Several forecasting related data integrity issues were studied in detail during earlier SCSL projects and are provided for reference in APPENDIX C. However, one important issue that needs to be emphasized is the possibility of a single product having multiple selling units of measure. In such cases, it is critical that the base data is aggregated properly by reconciling different selling units of measure. Figure 4.9 illustrates consolidation of sales quantity for an item that has been sold in different units of measure.

Figure 4.9 Reconciliation of Different Selling Units of Measure

Loc No.	Item No.	Month	UoM	Qty Sold	Stocking UoM	Eff. Qty Sold
L1	PVC45	200308	TN	290	FT	2900
L1	PVC45	200309	TN	198	FT	1980
L1	PVC45	200310	TN	215	FT	2150
L1	PVC45	200311	TN	156	FT	1560
L1	PVC45	200312	TN	201	FT	2010
L1	PVC45	200308	FT	1090	FT	1090
L1	PVC45	200309	FT	1480	FT	1480
L1	PVC45	200310	FT	340	FT	340
L1	PVC45	200311	FT	200	FT	200
L1	PVC45	200312	FT	160	FT	160
L1	PVC45	200308	LG	273	FT	5460
L1	PVC45	200309	LG	128	FT	2560
L1	PVC45	200310	LG	91.5	FT	1830
L1	PVC45	200311	LG	145	FT	2900
L1	PVC45	200312	LG	80	FT	1600

UoM Conversion Factors
1 TN = 10 FT
1 LG = 20 FT

After UoM Reconciliation		
Stkg. UoM	Month	Total Qty
FT	200308	9450
FT	200309	6020
FT	200310	4320
FT	200311	4660
FT	200312	3770

4.4 Replenishment Analysis

The implementation of replenishment analysis was expected to be difficult given the complex nature of the problem and lack of statistical knowledge at a layman level. Hence internship activities included developing simple tools that would address the basic needs of SCSL clients such as clarification of service level definitions, comparison of statistical re-order point (ROP) with client's existing "min" (of a min/max system), total relevant cost, and lead time calculation issues.

4.4.1 Service Level Definitions

As mentioned in Nahmias (2005), continuous review models that account for uncertain demand are the most popular inventory control models available in commercial information systems. They typically use service level settings instead of penalty costs that are difficult to obtain and implement. But the service level definition is probably the most misconstrued concept in practice in the realm of inventory management.

The difference between Type 1 (cycle service level) and Type 2 (product fill rate) service levels is rarely understood in the business world. Type 2 is how most people naturally think about service levels, yet typical statistical formulations for safety stock and re-order point settings are based on Type 1 service level. Also, sometimes the performance metrics used by companies to measure fill rates by sales order, product group, customer, etc get mixed up with this topic.

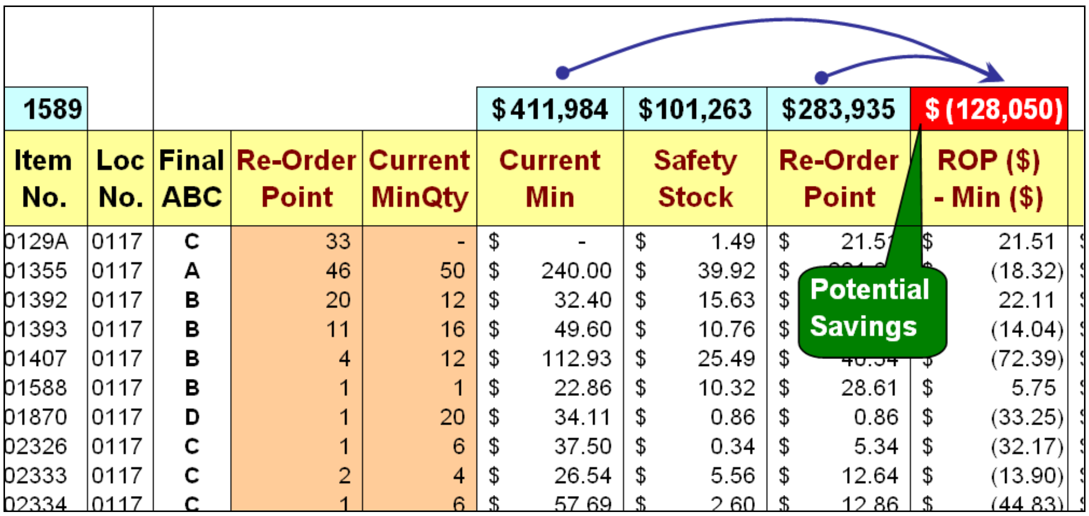
Fundamentally, service levels are set based on stratification ranks and by default people tend to associate a higher number such as 98% or 99% for high ranked items. In these situations, it is difficult to convince the companies that a cycle service level of 75% or 80% would achieve the same or possibly higher performance level. Due to this reason, majority of the time service levels are set at much higher levels than necessary since the settings are typically input parameters for users.

On the other hand, to use a different formulation based on Type 2 service level the challenge was in obtaining appropriate order quantities which is a requirement to compute the safety stock and re-order point. So in order to strike a balance, the safety stock and re-order points were calculated using Type 1 formulation but also in addition Type 2 service levels were computed wherever possible so that the user could see the interdependence and manipulate input parameters accordingly.

4.4.2 Comparison of System Min and Statistical ROP

The key objective of performing a statistical ROP calculation for a client was to demonstrate the value of implementing a new and better formulation compared to some rule of thumb which is normally the case (in spite of an inventory control software). This required obtaining a company's existing system min levels, if available, and comparing that with statistical re-order points recommended by SCSL. Figure 4.10 shows a screenshot of a spreadsheet that was setup to show at a sales branch / location level the potential decrease (or increase) in inventory value using a statistical ROP.

Figure 4.10 Comparison of System Min and Statistical Re-order Point



1589					$411,984	$101,263	$283,935	$ (128,050)
Item No.	Loc No.	Final ABC	Re-Order Point	Current MinQty	Current Min	Safety Stock	Re-Order Point	ROP ($) - Min ($)
0129A	0117	C	33	-	$ -	$ 1.49	$ 21.51	$ 21.51
01355	0117	A	46	50	$ 240.00	$ 39.92	$ [illegible]	$ (18.32)
01392	0117	B	20	12	$ 32.40	$ 15.63	$ [illegible]	22.11
01393	0117	B	11	16	$ 49.60	$ 10.76	$ [illegible]	(14.04)
01407	0117	B	4	12	$ 112.93	$ 25.49	$ [illegible]	$ (72.39)
01588	0117	B	1	1	$ 22.86	$ 10.32	$ 28.61	$ 5.75
01870	0117	D	1	20	$ 34.11	$ 0.86	$ 0.86	$ (33.25)
02326	0117	C	1	6	$ 37.50	$ 0.34	$ 5.34	$ (32.17)
02333	0117	C	2	4	$ 26.54	$ 5.56	$ 12.64	$ (13.90)
02334	0117	C	1	6	$ 57.69	$ 2.60	$ 12.86	$ (44.83)

4.4.3 Total Relevant Cost

Using the three critical cost factors – ordering, holding, stock-out – an automated spreadsheet was setup to calculate total relevant cost at an Item-Location level. This was an excellent tool for branch managers to see the interplay of these cost factors at a detailed level. But unlike the holding cost factor, which is usually accepted to be in the range of 40% to 60% of unit cost, it was difficult to establish consensus on ordering and stock-out costs. In particular, stock-out cost is an extremely complex factor that varies by customer type, product type, mix of products in the customer order, etc. Figure 4.11 shows a screenshot of the spreadsheet tool having the total relevant cost at an Item-Location level along with all the necessary user input parameters in yellow colored cells.

Figure 4.11 Total Relevant Cost Calculation

Order Cost ($)	
$50	
Holding Cost (%)	
40%	
Stock-out Cost (%)	
250%	

Cycle Service Levels (%)		Z
A	99%	2.33
B	95%	1.64
C	80%	0.84
D	70%	0.52
Others	70%	0.52

ItemNo	Ordering Cost	Holding Cost (for Regular Stock)	Holding Cost (for Safety Stock)	Stock-out Cost	Total Relevant Cost
1232	$ 29,181	$ 350,177	$ 78,787	$ 11,804	$ 469,949
0014A	$ 81.81	$ 981.76	$ 678.02	$ 88.07	$ 1,829.67
0016A	$ 35.41	$ 424.98	$ -	$ -	$ 460.39
0017A	$ 38.39	$ 460.66	$ 143.21	$ 91.15	$ 733.41
0018A	$ 112.22	$ 1,346.66	$ 1,195.96	$ 213.10	$ 2,867.94
0019A	$ 78.55	$ 942.62	$ 781.30	$ 97.44	$ 1,899.92
0020A	$ 174.16	$ 2,089.94	$ 982.58	$ 2,837.43	$ 6,084.11
01091	$ 118.27	$ 1,419.27	$ 1,835.52	$ 39.53	$ 3,412.59
01588	$ 14.48	$ 173.72	$ 4.61	$ 3.03	$ 195.84
01870	$ 26.06	$ 312.77	$ 24.56	$ 1.02	$ 364.42
03521	-	$ -	$ -	-	$ -
0375A	$ 16.48	$ 197.82	$ 6.09	$ 1.67	$ 222.06
0381A	$ 50.43	$ 605.15	$ 173.49	$ 1.59	$ 830.67

4.4.4 Data Integrity Issues

Lead time data is one of the key determinants of the ROP levels but is often prone to over-simplified or even erroneous calculations. When calculating lead time average and standard deviation from historical purchase orders, the following factors at a minimum need to be considered:

- **Timeline:** Representative purchase order history to reflect market realities.
- **Outliers:** Procedure to statistically remove outliers in lead time data.
- **Multiple shipments:** Proper definition of the receipt date to be considered.
- **Receipt reversals:** Systematic elimination of negative receipts.

Figures 4.12 and 4.13 illustrate the issue of outliers and multiple shipments on a real-time dataset for a client. In the case of outliers, a standard procedure was established to remove data points above two times (user controlled variable) above or below the standard deviation. For multiple shipments, a certain (user given) percentage of receipt quantity was used as a threshold to pick the corresponding receipt.

Figure 4.12 Outliers in Lead Time Data

Lead time outliers can be identified based on Std. Deviation limits.

Item No.	Loc No.	Order No.	Line No.	Order Date	Order Qty	Receipt Date	Receipt Qty	Lead Time
B188	L1	828747	5	5-Jan-06	180	11-Jan-06	180	6
B188	L1	851991	2	22-Jan-06	225	27-Jan-06	225	5
B188	L1	874213	3	2-Feb-06	320	6-Apr-06	320	63
B188	L1	880032	7	10-Feb-06	150	15-Feb-06	150	5
B188	L1	891234	4	3-Mar-06	100	10-Mar-06	100	7
B188	L1	905637	1	17-Mar-06	125	22-Mar-06	125	5
							Average ==>	15.17

Figure 4.13 Impact of Multiple Shipments on Lead Time Definition

Purchase Order					
Item No.	Loc No.	Order No.	Line No.	Order Date	Order Qty
0101A	L3	123123	1	9-Feb-06	500
:	:	:	:	:	:
:	:	:	:	:	:

Need to appropriately determine the actual lead time considering relevant business factors.

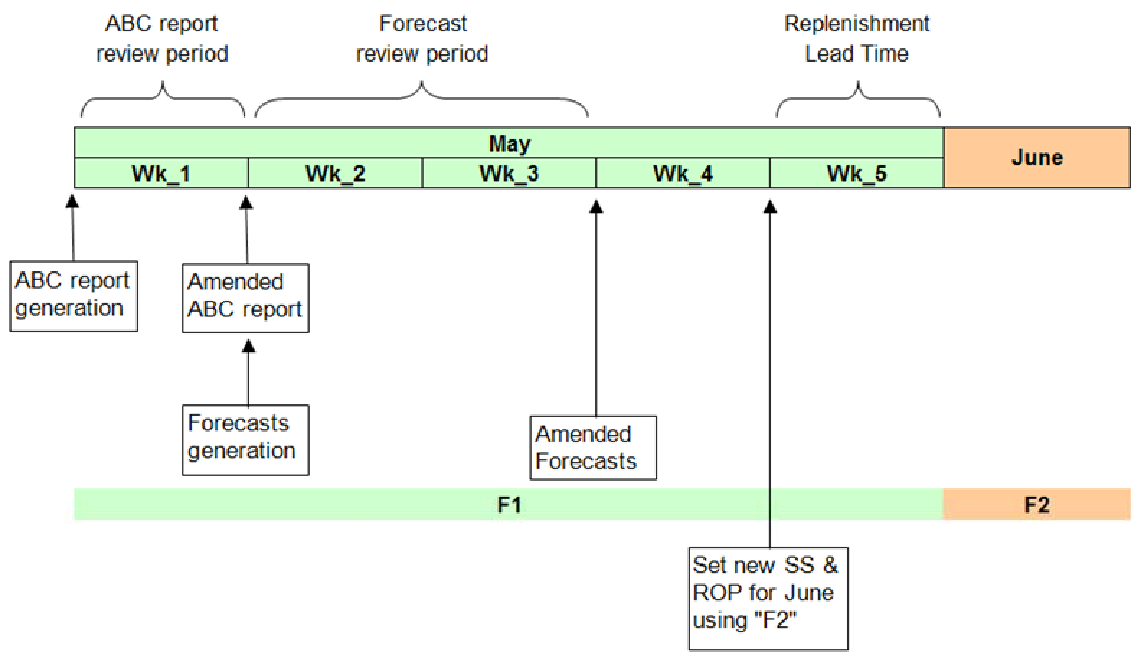
Purchase Order Receipt							
Item No.	Loc No.	Order No.	Line No.	Receipt Date	Receipt Qty	Lead Time ???	
0101A	L3	123123	1	15-Feb-06	200	6	<== 1st Shipment
0101A	L3	123123	1	21-Feb-06	200	12	<== 2nd Shipment
0101A	L3	123123	1	10-Mar-06	100	29	<== 3rd Shipment
:	:	:	:	:	:		
:	:	:	:	:	:		

In certain situations, lead time data had to be set directly by the user rather than calculating from historical purchase orders. A scenario would be when defining the lead time from a company's central warehouse to its branches. One cannot simply assume or set the lead times based on the distance between the locations since several components make up the actual lead time some of which are given below:

- Warehouse logistics issues like several pick tickets already in queue.
- Drop calendars followed by the trucks for regular scheduled delivery.
- Actual shipping time between the locations based on mode of transportation.
- Check-in procedure for received inventory at the branch that determines if inventory is indeed available in the information system for release to sales orders.

Apart from the lead time issues, an overarching factor with implementing basic ROP formulation is the *timing of various inventory analysis reports* that need to be generated and reviewed by planners. Typically a week is required for reviewing and amending stratification ranks followed by another two weeks for amending system generated forecasts. This means that all the amended data can be effectively used only for the next month than the current. So, the formulations had to be set based on the second month in the forecast horizon. This also affected the forecast error metrics calculation. Figure 4.14 illustrates this issue for a five-week month with an assumption of less than one week replenishment lead time. This would of course get more complex for long lead times.

Figure 4.14 Time Lag Issue with Various Inventory Analysis Reports



4.5 Contributions and Benefits

The internship activity directly and indirectly contributed to several benefits for internal lab operations, its clients, and the business and IT community at large. Some of the key contributions and benefits are discussed below.

4.5.1 Growth in Implementation Knowledge Base

The iterative process of data analysis planning (model and data specifications) and execution (automation and standardization) phases in SCSL projects enabled identification and exploration of key real-world factors (like location, product, and transactional attributes) that need to be addressed during implementation of analysis programs. This led to fine-tuning and/or extending theoretical models and methods, in the context of inventory management, to cater to real business needs. This iterative process naturally helped accelerate the growth of implementation knowledge base that proved to be critical in virtually all of SCSL projects thereafter.

4.5.2 Savings Achieved by Client Firms

The immediate beneficiary of SCSL's streamlined inventory management analyses in the client base was of course Wilson. Their management team was aggressive in implementation and the company went on to achieve the following inventory savings:

- Reduction of *$3M* non-tubular inventory between Oct 2005 and Aug 2006.
- At branches: Reduction of 10 days in days of coverage translating to *$12M*.
- At DCs: Reduction of 8 days in days of coverage translating to *$8M*.

As identified earlier, inventory stratification is the most important of all the inventory management processes from a ROI standpoint especially for distributors whose largest asset is inventory. After the Wilson project, several companies engaged SCSL specifically on inventory stratification projects to realize immediate bottom line savings. They eventually reaped the benefit, a sample of which can be seen in Figure 4.15 below.

Figure 4.15 Inventory Savings of SCSL Clients

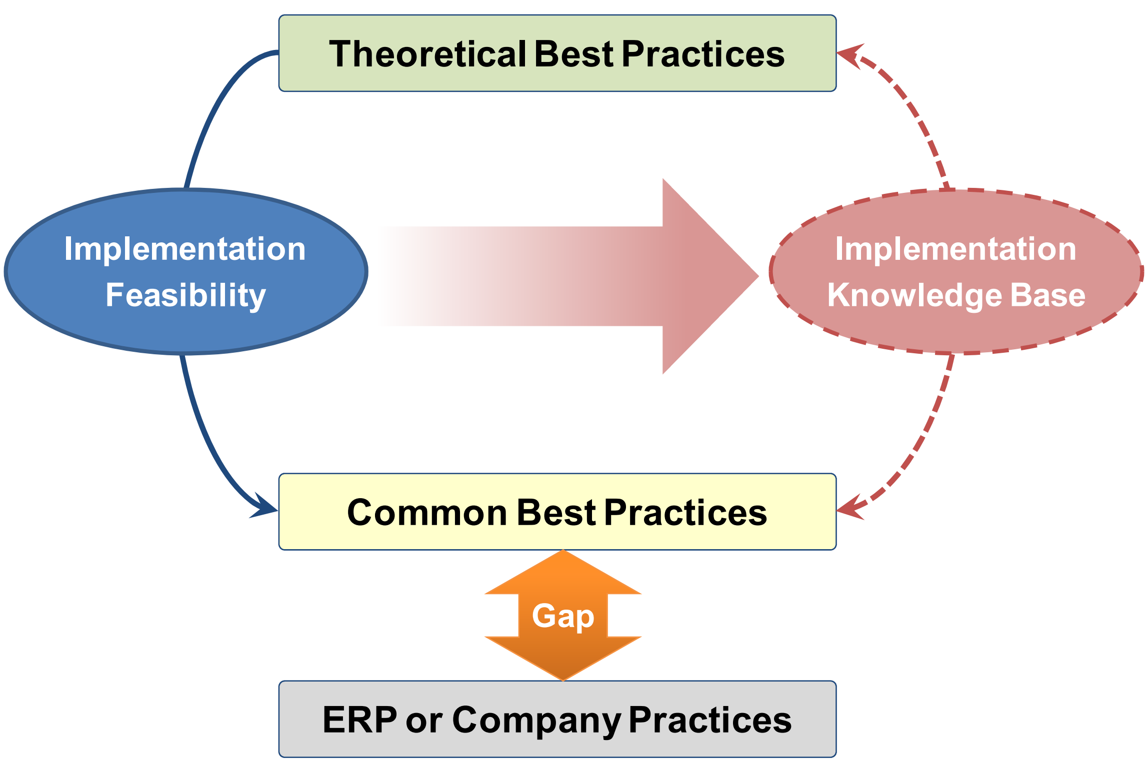
Project Area	Industry	Revenue	Recommended Value Addition
Inventory Stratification	Oil and Gas Mfg & Services	$1 Billion	20% Inventory Redeployment *
	Metals Distribution	$1 Billion	17% Inventory Reduction
	Building Materials Distribution	$80 Million	22% Inventory Reduction
	Fluid Power Equipment Distribution	$125 Million	33% Inventory Reduction
	Paper Manufacturing	$220 Million	10% Inventory Redeployment
	Hardware Distribution	$125 Million	35% Inventory Reduction
	Oil and Gas Distribution	$1 Billion	12% Inventory Reduction *

Along with increased customer service level

4.5.3 Knowledge Dissemination

As a part of an academic institution focused on creating competitive advantage for the industry, SCSL's role in creating and disseminating knowledge to the business community is vital. An opportunity to engage with the IT provider PeopleSoft, later acquired by Oracle, resulted in creation of a best practices report on all major distribution business functions. The idea behind the report was to compare and contrast theoretical, common, and company / system practices. As can be seen in Figure 4.16, SCSL's implementation knowledge base, including those contributed by the internship activities, was leveraged. The report was eventually published by the National Electronics Distributors Association (NEDA) for the benefit of distribution community (Texas A&M University Supply Chain Systems Lab 2007).

Figure 4.16 Best Practices Framework



4.5.4 Commercial ERP System Implementation

When we consider the process of theory to practice conversion and its degree of penetration in the real-world, the best way to have a mass impact is through commercialization. This can be effectively done with the help of IT organizations that are the intermediary between academia and industry since they incorporate theoretical concepts into their software subject to real-world business constraints. This process gets accelerated when IT companies work with applied research entities such as the SCSL.

Infor, one of the leading enterprise software solution providers, partnered with SCSL to upgrade their inventory management software module in their ERP system (called as SX.e). Much of the internship work on inventory management analysis programs was leveraged for this purpose. Infor’s next software version release (expected in mid to late 2009) is expected to incorporate the SCSL inventory analysis framework which would then reach a wider industry audience. This will undoubtedly serve SCSL’s mission.

5. ORGANIZATIONAL FACTORS, CHALLENGES, AND SOLUTIONS

5.1 New Business Models

After completion of a data analysis project, companies typically proceed with implementation of the methodology within their IT systems. Soon it became obvious that the companies needed SCSL team's continued expertise during implementation due to their deep knowledge of operational details gained during the project. So, three new business models were developed for assisting companies with IT implementation and are described below. Some of the unique features of these business models were:

- Low "cost to serve" due to leverage on already established data processes.
- Minimal effort to close the sale for these follow-on projects from existing clients.
- Expansion of implementation knowledgebase due to further real-world exposure.
- Opportunity to develop close working relationship with clients.

5.3.1 Domain Knowledge Transfer

The most common requirement from clients was to help their IT personnel understand the customized methodologies developed during the analysis project so that they can program it within their systems. In this situation, several technical education sessions are conducted for the IT personnel to walk through all the data execution steps performed by SCSL.

5.3.2 Operations Outsource

In many situations, even if the company was willing to proceed with domain knowledge transfer, they would find their IT resources already committed to other projects for many months ahead. In these cases, SCSL would continue to periodically re-run analyses and refresh results for a short term until the client's IT team was ready. This was basically a model where SCSL would act as an "operations outsource" for the company.

5.3.3 Bolt-on Software Solution

This business model was actually a response to some industry requests for an on-site deployment of SCSL's internal productivity tool and was not actively pursued by SCSL. This topic was also covered earlier in the third section where the portability and bolt-on capability of the tool was mentioned. The main drivers for this business model were:

- Long cycle time required for IT providers to upgrade their enterprise system.
- Competitive necessity for companies to immediately leverage on cutting edge programs rather than wait for software upgrade release by their IT provider.
- Small companies that already have a home grown system and want to just plug the SCSL tool into their IT ecosystem.

5.2 Proposal Scope Management and Budgeting

Many of the earliest proposals sent as responses to industry RFPs (Request for Proposals) did not have sufficient technical details which led to project scope creep situations since a company's interpretations were different from what was intended in the proposal. In some scenarios projects based on open-ended proposals were already underway in which case automation tools were leveraged to certain extent to minimize the damage if not completely avoiding them.

More importantly, the proposals in the pipeline yet to be approved were supplemented with appropriate details that clearly defined the project scope. Insights from data analysis automation and standardization processes proved to be instrumental in appropriately defining the level of detail of a project. This helped estimate the required SCSL workload and hence price the project accordingly. In some instances, even the clients would get enlightened about the scope of activity and the required time and resources. Some of the key factors considered for scoping a project are:

- Number of locations / branches to be analyzed.
- Delineation between various inventory analyses (for example, stratification vs. forecasting analysis).
- Client's IT capability and data quality.
- Number of data analysis iterations.
- Level of customization potentially required for standard methodologies.
- Potential follow-on projects for implementation support.
- Possibility of the client becoming a core / strategic partner.

5.3 Human Resource (Crisis) Management

Human resource challenges are common in all types of organizations but SCSL's unique nature of applied research work especially within a University setting made things quite difficult. The exponential growth experienced during 2004-05 only exacerbated the situation. Automating and standardizing many processes somewhat alleviated the pressure on the research team but there was a limit to it since the complexity of incoming projects had increased quite considerably compared to the early 2000s.

5.1.1 Full-time Employees

Multiple funded research projects required dedicated full time project leaders / managers in order to constantly engage the client including regular on-site visits, project update meetings, technical sessions, hosting client meetings at A&M, etc. But system constraints, such as the ones listed below, posed difficulty in hiring and/or retaining high caliber full time research candidates:

- Unattractive pay scale in spite of demanding high quality work required.
- Lack of clear and convincing career track for a research staff when compared to a faculty and general concerns about future career outlook.
- Lack of mechanisms to appropriately compensate knowledge *creators* as opposed to only the *disseminators*.
- Workplace constraints that at times hindered with work efficiency and were not very conducive for innovation, a key ingredient for a budding team's success.

5.1.2 Graduate Assistants

Given the difficulty to attract and hire full time researchers, Graduate Assistants (GAs) were the only choice and that too from a restricted pool of available resources. It was a constant struggle to manage GAs due to several reasons as listed below:

- Learning curve of at least three to four months on an average which was too slow for the kind of SCSL activities and client expectations.
- Constant need for verification and validation of GA work output to prevent embarrassments in front of clients.
- Differing priorities (student holidays vs. project deadlines) and many times a general lackluster attitude towards work.
- More importantly, lack of ROI on project manager's time and effort invested in training GAs due to their short stint at SCSL (typically one year).

The best that could be done was to ensure selecting the best of the lot by following a strict filtering process while hiring GAs and/or other part time employees. In this regard, a detailed formal interview process was developed that included a written test to objectively test the skill set of a candidate. Many times, this requirement had to be relaxed due to lack of an acceptable pool of candidates to choose from.

5.4 Information Technology Administration

5.4.1 Average Inventory Calculator Tool for Clients

As mentioned in section 4.2, due to the criticality of inventory data history to perform a solid data analysis, the need for capturing the same was emphasized to clients even before any project engagement. The hope was that being pro-active would help secure at least a few months of inventory history prior to the data analysis phase of a project. But this was not always possible especially when clients did not have a good IT team. So, a simple MS Access based automation tool was developed that would connect with a client's IT system, capture daily inventory snapshots, perform a running average calculation, and store the monthly inventory average figures.

5.4.2 Leveraging Website for Data Transfer

The large number of data analysis projects and their size demanded the capability for SCSL to exchange considerable volumes of data with clients. But the IT infrastructure was yet to be configured to support this need and hence an innovative solution was devised to quickly solve this important operational issue. A new webpage on SCSL's website was developed to be used as a front-end for clients to upload and download datasets. A screenshot of this webpage is given in APPENDIX A.

5.5 Organizational Two-way Bull Whip Effect

The internship experience clearly indicated the need to align the activities of Management (those who face / engage SCSL clients) and Operations (research team who perform the actual work). A lack of understanding and appreciation of each other's role leads to an organizational two-way bull whip effect.

When Management does not have a basic idea of the operational know-how, it leads to:

- Incorrect estimation of operational workload and time/effort required for various tasks (underestimation more common than overestimation).
- Underpriced projects and infeasible project design.
- Constant and surprise deadline pressures on Operations leading to poor work quality, frustration, and ultimately burn-out.

Similarly, when Operations does not understand the big picture, it leads to:

- Ineffective prioritization of tasks and allocation of resources.
- Intermittent, sloppy, quick fix solutions to problems with the benefit being less than the overall cost.
- Lack of motivation to create SOPs (Standard Operating Procedures) which in the long term leads to inconsistency and reinventions.

6. SUMMARY AND CONCLUSIONS

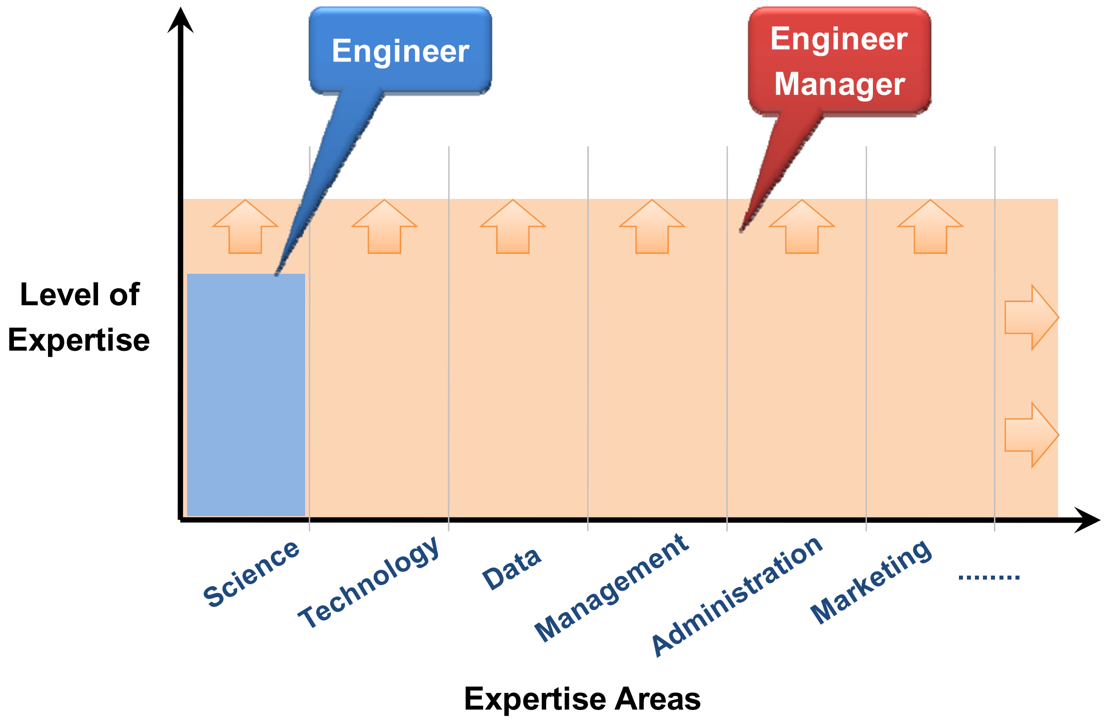
The DE internship enabled me to achieve the two primary objectives stated in the program manual; firstly, application of technical knowledge by making an identifiable contribution in an area of practical concern to the intern employer and secondly, functioning in a non-academic environment to become familiar with organizational approaches to problems such as management and labor.

The first objective stated above was accomplished through two major related activities, namely the design and development of an automated inventory management software tool for increasing productivity of SCSL research team members and the identification of challenges and solutions to problems that arise during practical implementation of inventory theory in the real-world. This required taking a holistic approach to problem-solving by accounting for both technical and non-technical factors.

The second objective was achieved through active participation in and contributions to overarching organizational activities including project management, business strategy, human resources management, communication, and IT administration.

In summary, the internship experience enabled me to develop and exhibit expertise in a gamut of subject areas not restricted to science and engineering. It turned out to be an excellent platform that transformed me from being an engineer to an *engineer manager*, perhaps equivalent to that of being a *master of all trades*. This is represented in Figure 6.1 wherein an engineer manager seeks to expand his/her breadth of expertise areas while simultaneously striving to gain more depth and knowledge in each area. Also, this process involves an inevitable *cross-pollination of ideas and techniques* that lead to a unique decision-making style and effective solution methodologies.

Figure 6.1 Engineer vs. Engineer Manager



Technology played an important role during the internship and it showed that when leveraged properly, technology can solve or at least considerably reduce the intensity of many problems previously deemed as insurmountable. Looking at the enterprise world, one cannot ignore the fact that MS Office Suite (especially Excel, PowerPoint, and Word) and MS Access are the most used tools and will remain so for a considerable amount of time. This was the case with every single project company that partnered with SCSL. Yet, hardly a few fresh graduates and others entering the job market are properly trained in these tools. Institutionalizing relevant training programs in these areas would greatly benefit individuals and organizations as a whole.

In an information age, this has a greater implication for knowledge workers, service providers, and in particular future managers whose young sub-ordinates (such as Generation Y) would include technology savvy individuals. Apart from organizational efforts, it is hoped that people in general will have the enthusiasm, due diligence, and patience to leverage the right tools to increase their personal productivity.

With respect to practical applicability of inventory theory, it is hoped that the given framework of real-world factors influencing data analysis and business decision-making would serve as a starting point or reference for inventory practitioners. In particular, factors related to data such as availability, proper specifications, and integrity issues during implementation need to be given their due attention and explored further.

Tiwari and Gavirneni (2007) call for increasing collaboration between researchers and practitioners to achieve synergy that will be beneficial to both communities. As a response, it cannot get better than having an applied research entity like the SCSL right within campus premises. Such organizations are critical for bridging theory and practice. It is hoped that the University environment will become more conducive to actively fostering such organizations by providing flexibility and due recognition to the individuals who in many ways risk their careers to contribute valuable knowledge to both industry and academia.

Lastly, degree programs that mold individuals as all-rounded personalities such as the Doctor of Engineering (DE) need to be actively marketed to attract good talented individuals who otherwise may not even be aware of the existence of such programs. Raman in his interview (Quinn 2005) states that supply chain management, if not management overall, is “in need of more missionaries than Bible writers” and that the missionaries “need both the hard and the soft skills”. Given the program’s intention, there is no doubt that DE graduates perfectly fit the shoes of a missionary and can act as an excellent conduit for both industry and academia.

REFERENCES

AberdeenGroup Market Alert. 2005. IBM and SmartOps Launch Super-Scale Inventory Optimization. Retrieved January 27, 2009 http://www.aberdeen.com/c/report/market_alert/ma_smartops_be_2180.pdf .

Eaves, A. 2002. *Forecasting for the Ordering and Stock-holding of Consumable Spare Parts*. Ph.D. Thesis, Lancaster University, UK.

Hadley, G., T. M. Whitin. 1964. *A Review of Alternative Approaches to Inventory Theory*. The RAND Corporation, Santa Monica, CA.

Hines, P., D. Taylor. 2000. *Going Lean*. Lean Enterprise Research Centre, Cardiff, UK.

Nahmias, S. 2005. *Production and Operations Analysis*. McGraw-Hill, New York, NY.

Quinn, F. 2005. Believe in miracles: An interview with Ananth Raman. *Supply Chain Management Review* **9**(2) 32-37.

Samuelson, D. 2005. Napolean's parable. *OR/MS Today* **32**(1) 72.

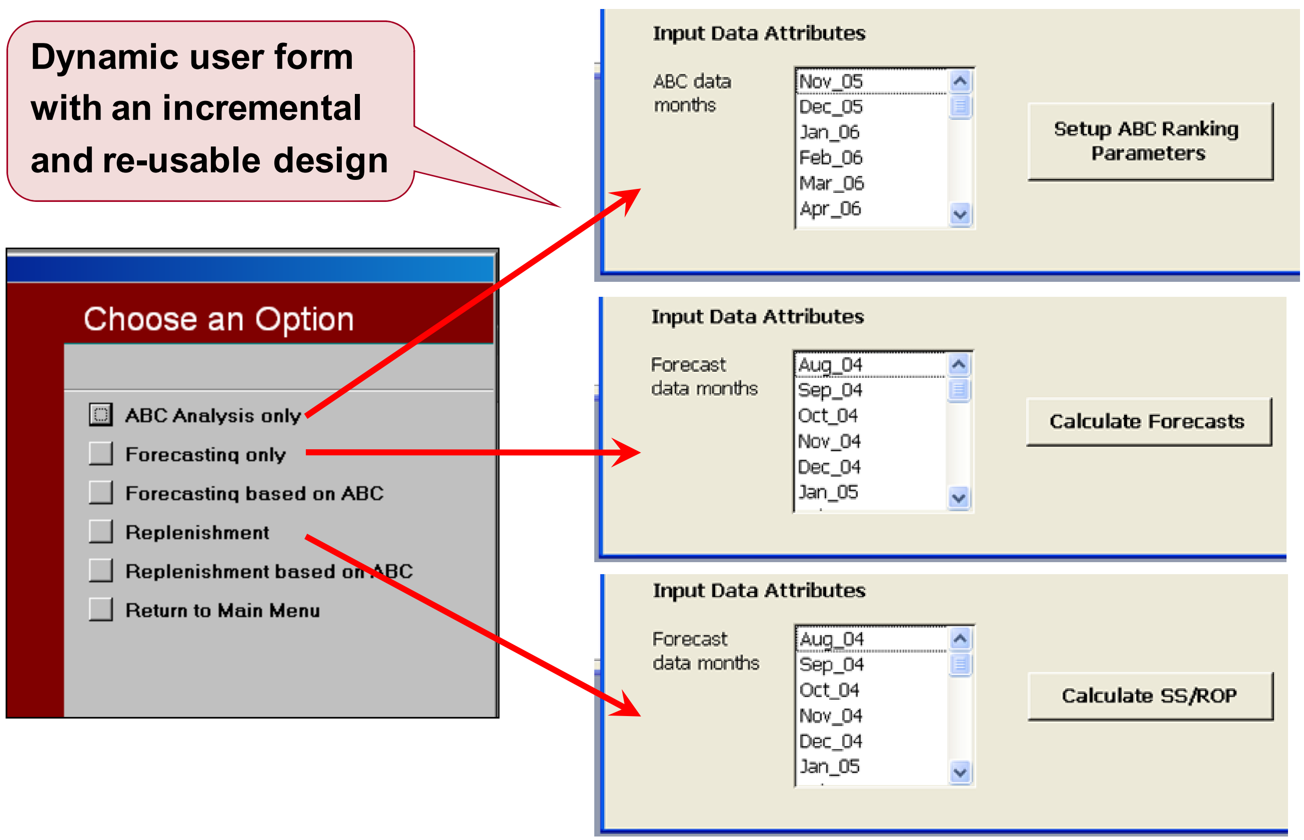
Texas A&M University Supply Chain Systems Lab. 2007. Wholesale distribution operational excellence: Best practices in information management. *Review of the Electronic and Industrial Distribution Industries* **6**(1) 96-145.

Tiwari, V., S. Gavirneni. 2007. ASP, The art and science of practice: Recoupling inventory control research and practice: Guidelines for achieving synergy. *Interfaces* **37**(2) 176-186.

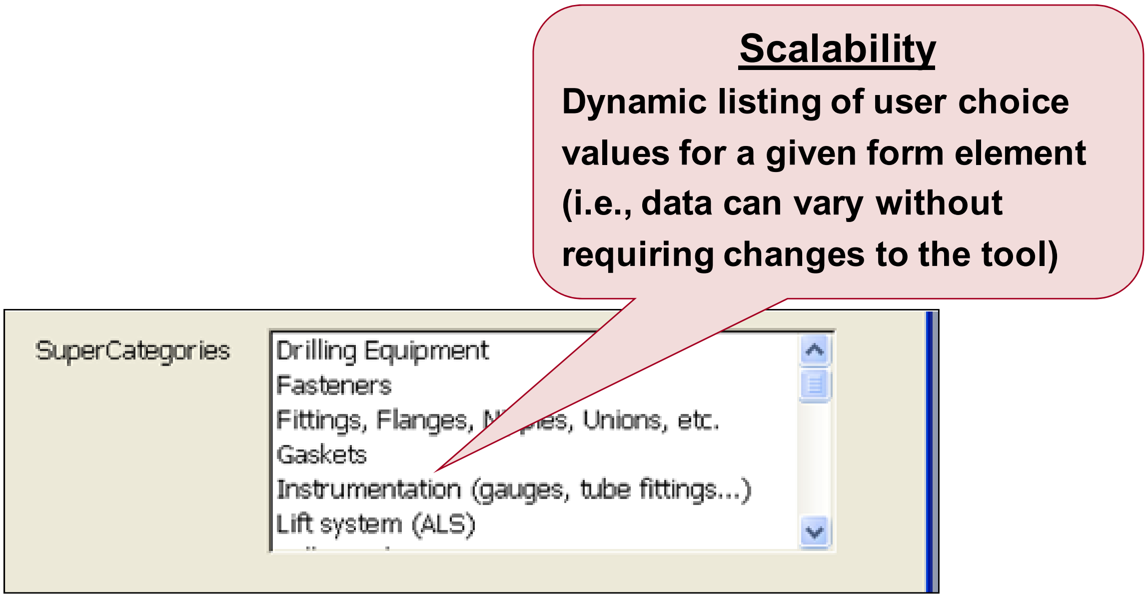
APPENDIX A

SCREENSHOTS OF SOFTWARE TOOL

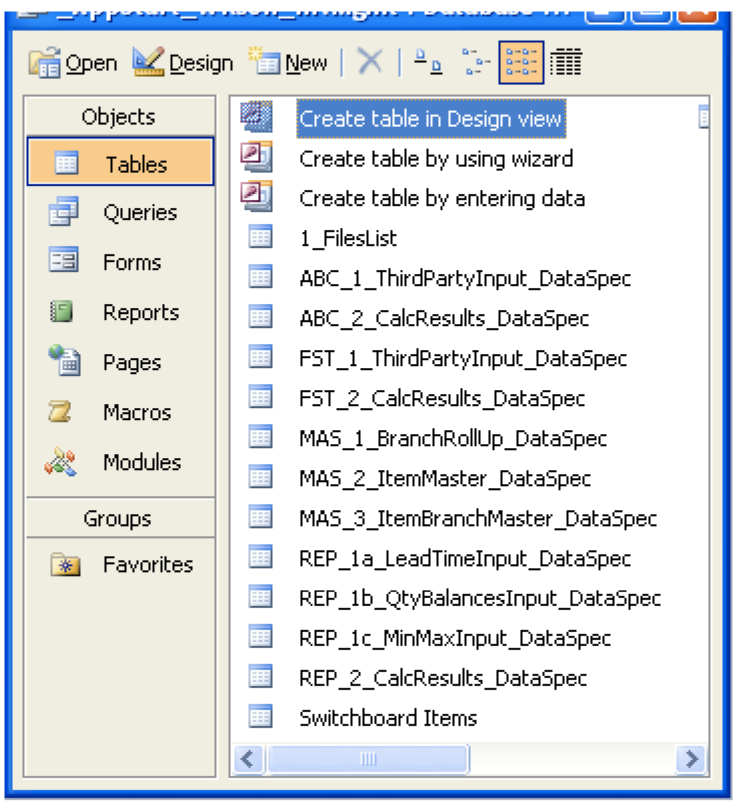
Example of Dynamic User Form Design



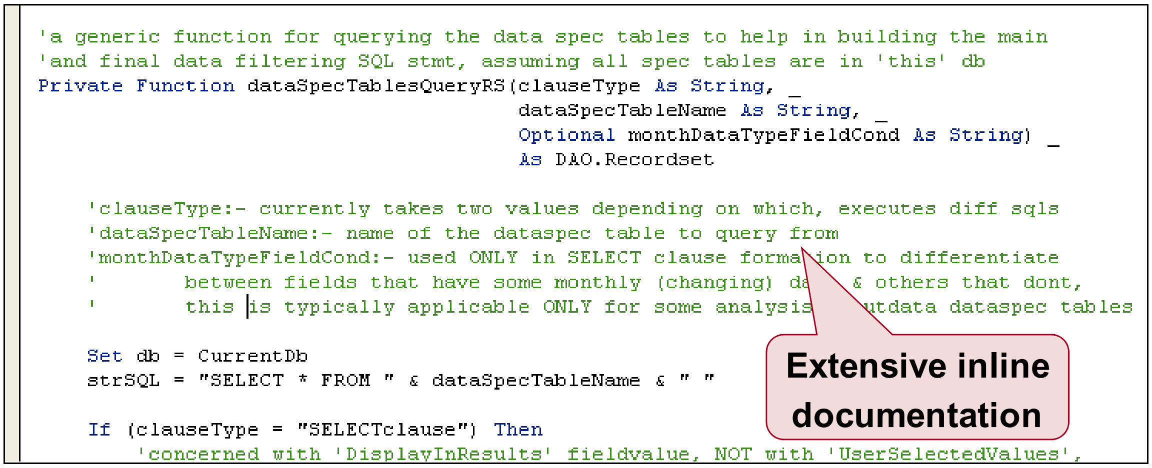
Example of Scalable User Form Design



Proper Naming Conventions for an Intuitive Experience



Code Snippet to Illustrate Inline Documentation



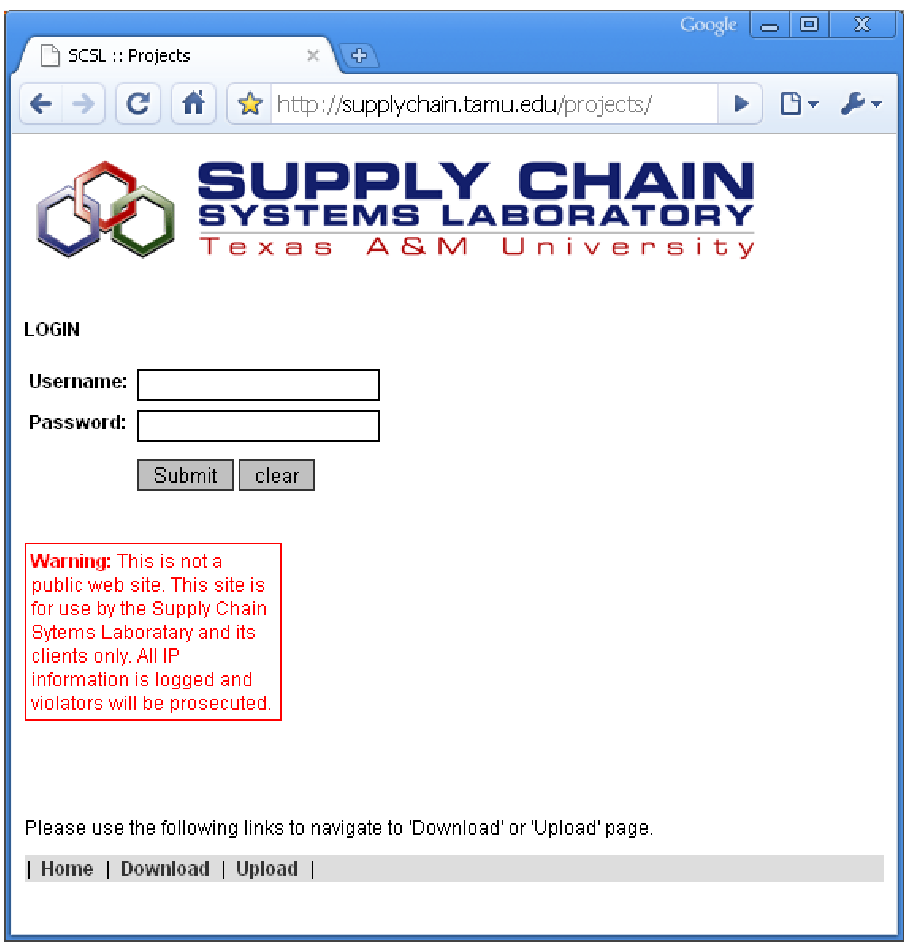
```
'a generic function for querying the data spec tables to help in building the main
'and final data filtering SQL stmt, assuming all spec tables are in 'this' db
Private Function dataSpecTablesQueryRS(clauseType As String, _
                                       dataSpecTableName As String, _
                                       Optional monthDataTypeFieldCond As String) _
                                       As DAO.Recordset

    'clauseType:- currently takes two values depending on which, executes diff sqls
    'dataSpecTableName:- name of the dataspec table to query from
    'monthDataTypeFieldCond:- used ONLY in SELECT clause forma  ion to differentiate
    '       between fields that have some monthly (changing) da    & others that dont,
    '       this is typically applicable ONLY for some analysis   utdata dataspec tables

    Set db = CurrentDb
    strSQL = "SELECT * FROM " & dataSpecTableName & " "

    If (clauseType = "SELECTclause") Then
        'concerned with 'DisplayInResults' fieldvalue, NOT with 'UserSelectedValues',
```


Screenshot of Webpage with upload/download page developed



APPENDIX B

DATA TEMPLATE AND RESULT REPORT SAMPLES

MASTER DATA

Latest snapshot before the data analysis phase.

Location Master

- ➢ Organizational rollup structure
- ▪ Location Number, Location Name, Region, etc.

Item Master

- ➢ Item attributes common at a corporate level
- ▪ Item Number, Item Description, Product Category, UOM, Stock or Non-Stock Status, Current Stratification Rank (if any), New Product Flag and other relevant item-level information.

Item-Location Master

- ➢ Item attributes at a specific location level, if any.
- ▪ Item Number, Location Number, Stock or Non-Stock Status, Current Location-specific Stratification Rank (if any), New Product Flag and other relevant fields.

TRANSACTIONAL DATA

Typically the recent 12 months prior to the data analysis phase.

Sales or Movements Data

- ➢ At a detailed level (ex: Order Line No. level)
- ▪ Item Number, Location Number, Month, Hits, Sales $, Cost $, etc.

Average Inventory Data

- ➢ At a Location-SKU level
- ▪ Item Number, Location Number, Month, Average or End-of-month Inventory $.

Pivot Table based Key Statistics for All Stratification Methods

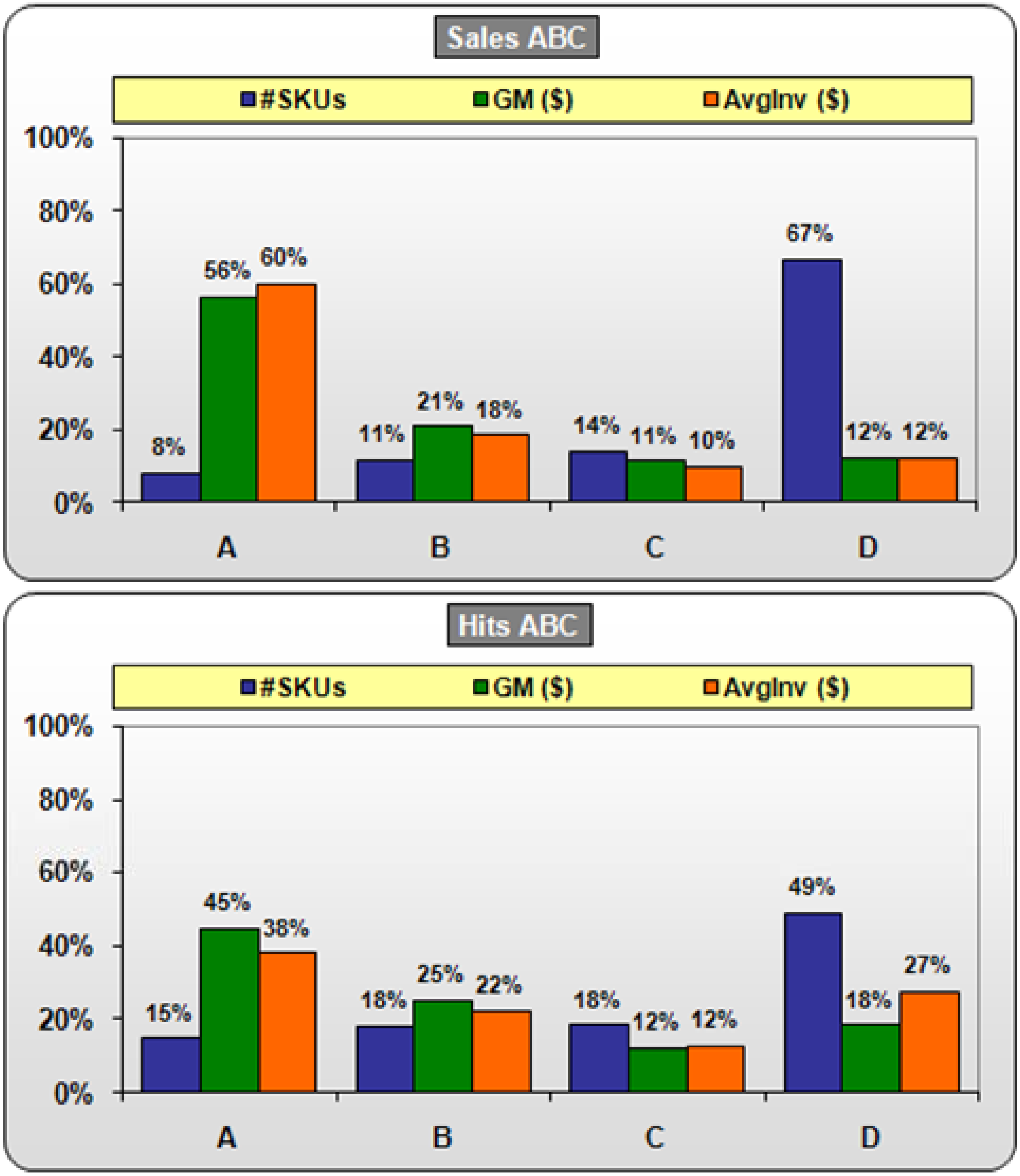
Sales_ABC	#SKUs	GM ($)	Cost ($)	AvgInv ($)
A	126	949,014	2,724,126	455,302
B	181	348,826	874,300	138,969
C	223	187,882	426,375	72,281
D	1,058	201,578	412,054	92,934
Grand Total	**1,588**	**1,687,301**	**4,436,855**	**759,486**

Hits_ABC	#SKUs	GM ($)	Cost ($)	AvgInv ($)
A	233	756,715	2,129,855	287,479
B	288	424,556	1,029,760	169,195
C	289	199,557	489,154	94,623
D	778	306,472	788,086	208,189
Grand Total	**1,588**	**1,687,301**	**4,436,855**	**759,486**

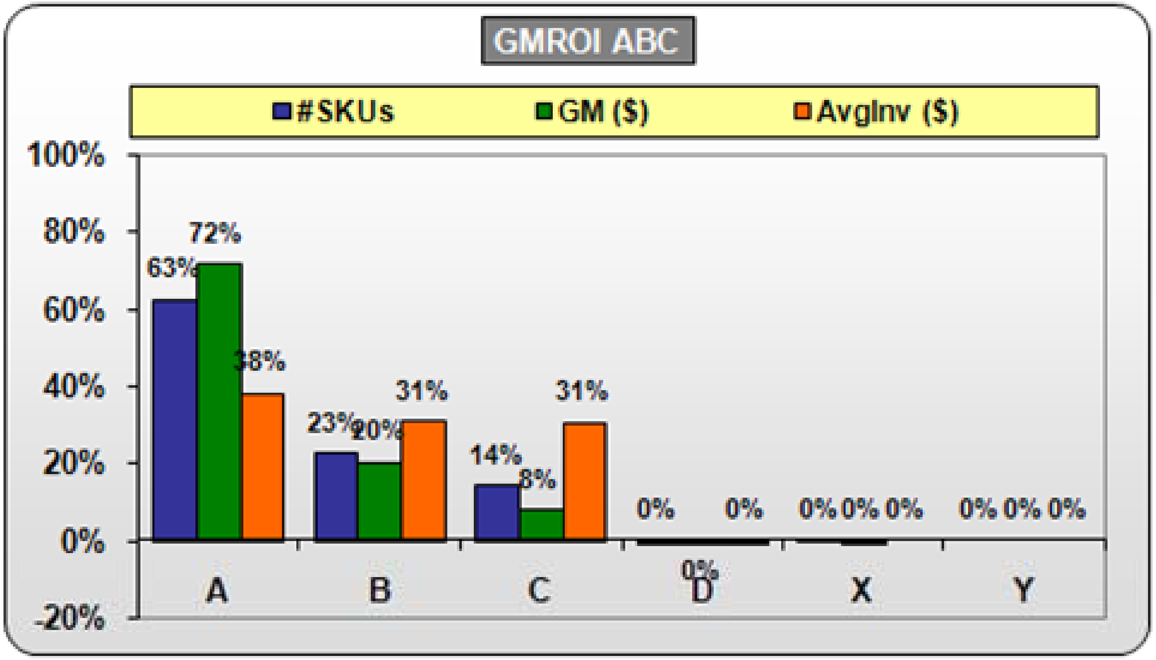
GMROI_ABC	#SKUs	GM ($)	Cost ($)	AvgInv ($)
A	994	1,208,072	2,549,515	291,576
B	364	345,192	1,263,499	234,926
C	227	133,684	621,629	232,830
D	1	(116)	739	154
X	2	468	1,472	-
Grand Total	**1,588**	**1,687,301**	**4,436,855**	**759,486**

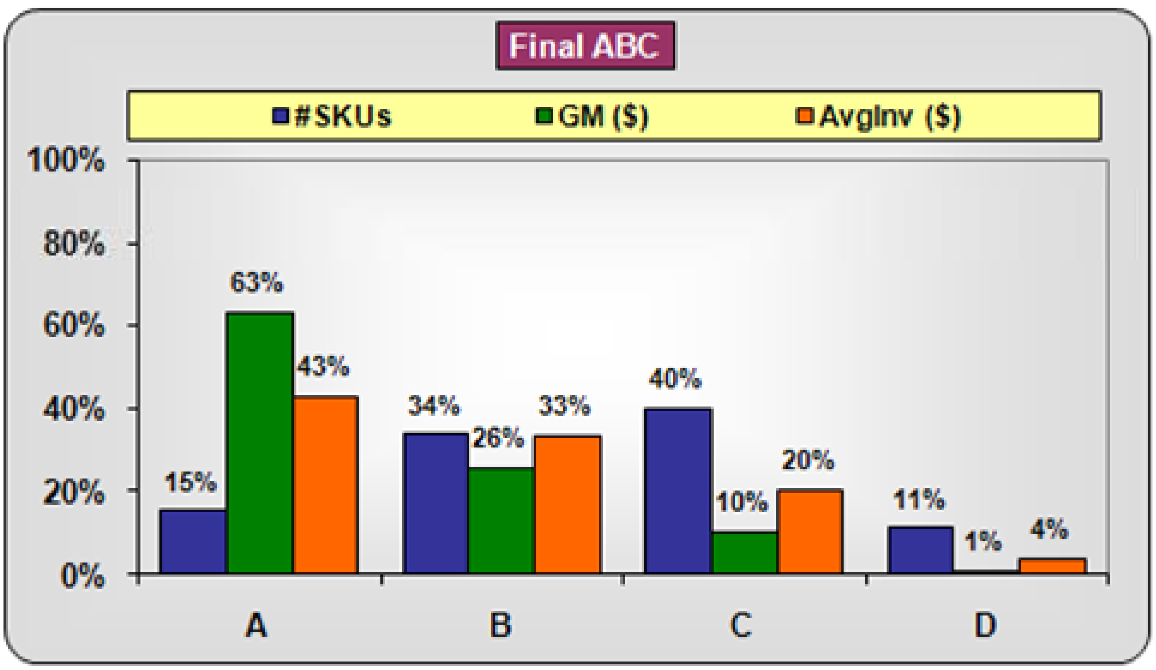
Final_ABC	#SKUs	GM ($)	Cost ($)	AvgInv ($)
A	243	1,064,632	2,657,059	325,123
B	535	433,660	1,235,223	253,346
C	632	175,547	500,496	153,718
D	178	13,461	44,076	27,300
Grand Total	**1,588**	**1,687,301**	**4,436,855**	**759,486**

Graphical View of Key Statistics (in %) for Sales and Hits Ranks



Graphical View of Key Statistics (in %) for GMROII and Final Ranks



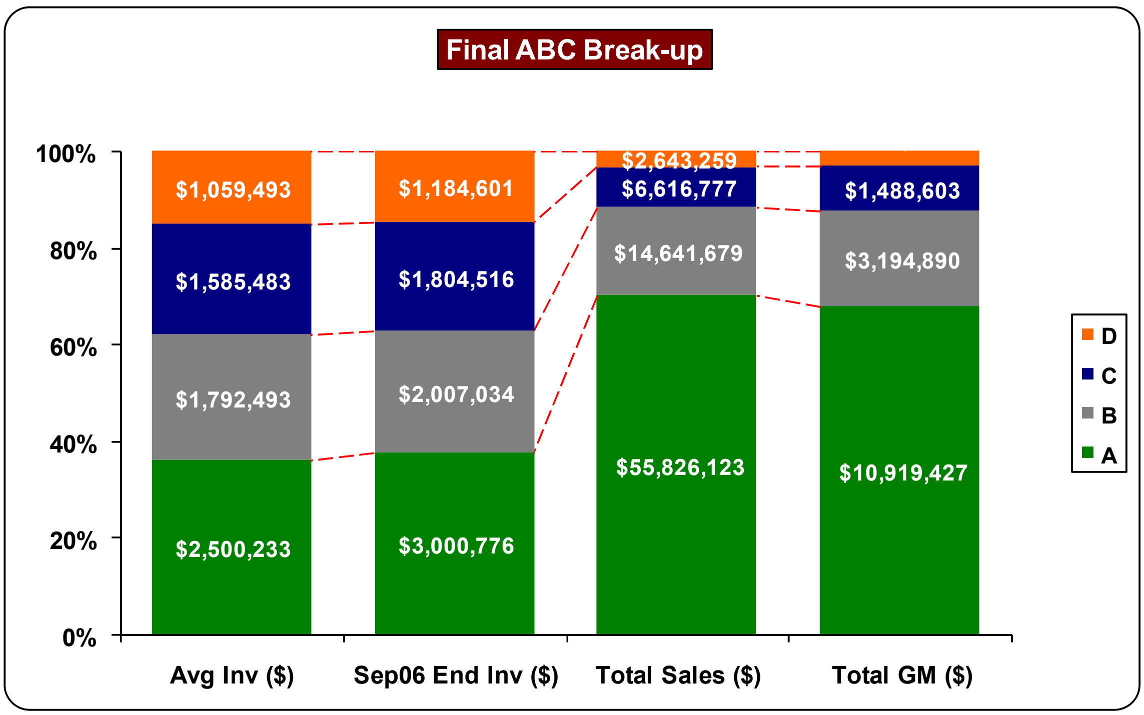


Pivot Table based Key Statistics for Final Rank with Filtering Options

Yard_Type	(All)
Region	(All)
Location_Name	(All)
Stock_Type	(All)

	Data			
Final_ABC	AvgInvValue ($)	Sum of Sep06_a	Total_Sales ($)	Total_GM ($)
A	$ 2,500,233	$ 3,000,776	$ 55,826,123	$ 10,919,427
B	$ 1,792,493	$ 2,007,034	$ 14,641,679	$ 3,194,890
C	$ 1,585,483	$ 1,804,516	$ 6,616,777	$ 1,488,603
D	$ 1,059,493	$ 1,184,601	$ 2,643,259	$ 521,822
Grand Total	$ 6,937,702	$ 7,996,927	$ 79,727,838	$ 16,124,741

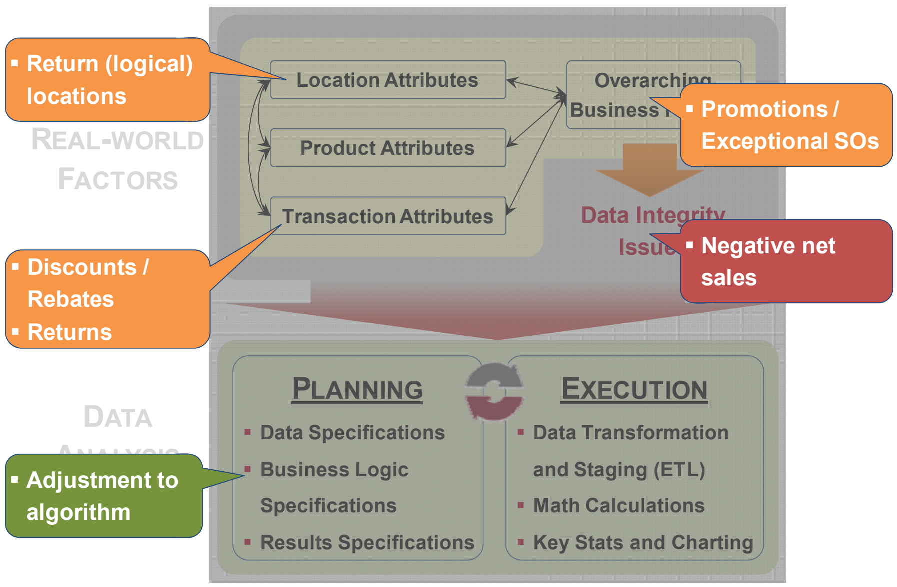
Graphical View of Key Statistics (both in % and $) for Final Rank



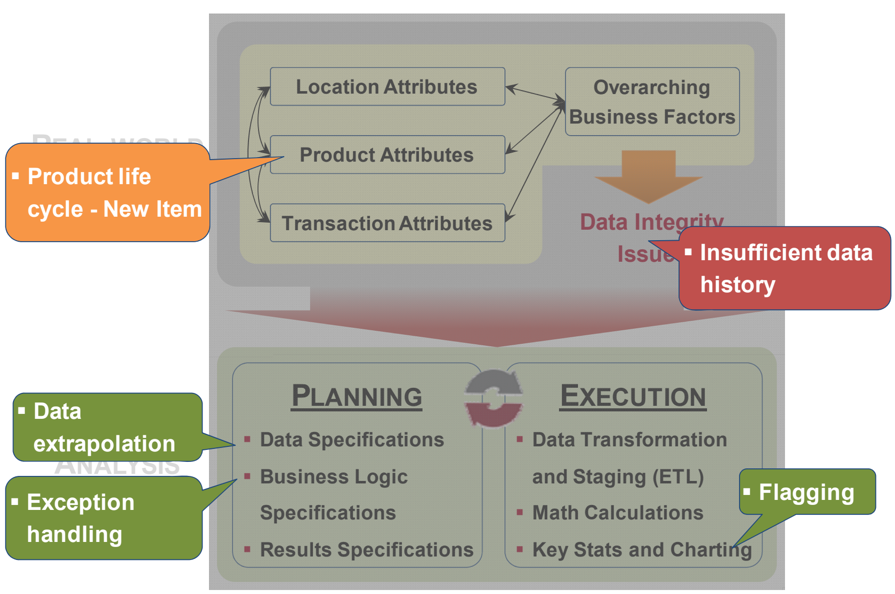
APPENDIX C

EXAMPLES OF DATA INTEGRITY ISSUES

Potential Reasons for Negative Net Sales



Need for Adapting Data Analysis due to Insufficient Data History



Impact of Negative Net Sales Data on Sales($) Ranking Method

Method 1 - 'Including' Negative Sales in Total

ItemNo	Product Family	Sales ($)	% of Total Sales	Cumulative Sales %	Rank
SO0OD	PVC	$ 101	26%	26%	A
A42143105	ELEC	$ 99	25%	51%	A
1FA632	ELEC	$ 79	20%	72%	B
ROP84	PVC	$ 54	14%	85%	C
FN0683209	MTL	$ 42	11%	96%	D
S0421	PVC	$ 41	11%	107%	D
350B3A	PVC	$ 34	9%	115%	D
015346EN	PVC	$ (15)	-4%	112%	D
FL2007EX	DRL	$ (45)	-12%	100%	D
	Total	$ 390			

[Note:- Ranking Criteria Used: 60-20-10-10 rule]

Method 2 - 'Excluding' Negative Sales in Total

ItemNo	Product Family	Sales ($)	% of Total Sales	Cumulative Sales %	Rank
SO0OD	PVC	$ 101	22%	22%	A
A42143105	ELEC	$ 99	22%	44%	A
1FA632	ELEC	$ 79	18%	62%	B
ROP84	PVC	$ 54	12%	74%	B
FN0683209	MTL	$ 42	9%	83%	C
S0421	PVC	$ 41	9%	92%	D
350B3A	PVC	$ 34	8%	100%	D
015346EN	PVC	$ (15)	-3%	97%	D
FL2007EX	DRL	$ (25)	-6%	91%	D
	Total	$ 450			

Same item(s) get different ranks due to different methods of calculating the total sales

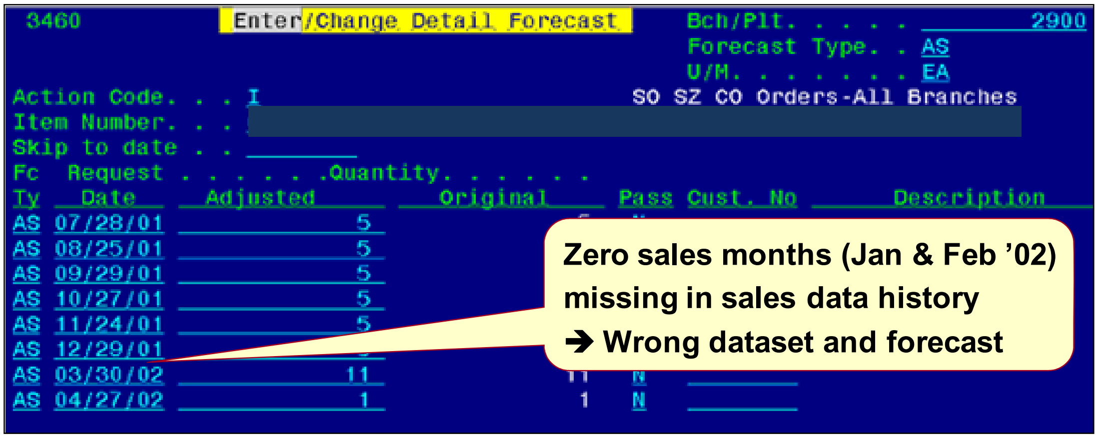
Impact of Relative Ranking on Sales($) Ranking Method

Rank all Product Families together					
ItemNo	Product Family	Sales ($)	% of Total Sales	Cumulative Sales %	Rank
SO0OD	PVC	$ 101	22%	22%	A
A421431005	ELEC	$ 99	22%	44%	A
1FA632	ELEC	$ 79	17%	61%	B
ROP84	PVC	$ 54	12%	73%	B
FN06832089	MTL	$ 42	9%	82%	C
S0421	PVC	$ 41	9%	91%	D
350B3A	PVC	$ 34	7%	98%	D
015346EN	PVC	$ 5	1%	99%	D
FL2007EX	DRL	$ 3	1%	100%	D

Rank only 'PVC' Product Family					
ItemNo	Product Family	Sales ($)	% of Total Sales	Cumulative Sales %	Rank
SO0OD	PVC	$ 101	43%	43%	A
ROP84	PVC	$ 54	23%	66%	B
S0421	PVC	$ 41	17%	83%	C
350B3A	PVC	$ 34	14%	98%	D
015346EN	PVC	$ 5	2%	100%	D

Item #S0421's rank changes from 'D' to 'C'

Wrong Data History and Forecasts



Demand Duplication for New Products with Insufficient History

Year\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	200	400	500	550								
2002	50	100	100	150	200	250	300	350	300	300	200	150
2001	50	100	100	150	200	250	300	350	300	25	200	50
2000					200	250	300	350	300	25	200	50

Item introduced in Oct ‘01

Averaging Logic for Months with Lost Sales

Year\Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	200	*450*	700	*700*								
2002	50	100	100	150	200	250	*300*	*300*	350	300	200	150
2001	50	100	100	150	200	250	270	310	330	25	50	50
2000					200	250	270	310	330	25	50	50

Average of Jun ‘02 and Sep ‘02

APPENDIX D

INTERNSHIP FINAL OBJECTIVES

The DE internship final objectives proposal submitted and approved by the committee in April 2005 is reproduced below.

April 3, 2005

To: Doctor of Engineering Advisory Committee
From: Sivakumar Sellamuthu
Re: Final Internship Objectives

This proposal describes the final objectives for my Doctor of Engineering (DE) internship conducted at the Supply Chain Systems Laboratory (SCSL) where I manage multiple funded research projects together with the support of multiple firms and research associates. It is my intention to request approval from the Advisory Committee for the same.

Introduction

The SCSL conducts several research projects in the distribution industry with a major area of focus in inventory management. A typical project model is on effective operational inventory management for small and mid-sized distributors conducted over a period of about 8 to 10 months and would include the following modules:

I. ABC analysis for proper inventory stratification.
II. Effective forecasting to more accurately estimate the demand.
III. Dynamic safety stocks and reorder points to reduce inventory carrying costs and increase customer service levels.
IV. Proper order quantity determination to aid in effective replenishment decisions.

With an exponential growth outlook, the lab is positioned to undertake several projects for large distributors and manufacturers that require focus on other areas of expertise such as multi-echelon supply chain models, Vendor Managed Inventory (VMI), and Key Performance Indicators (KPIs). This requires a significant need for investing more resources in these subject areas and at the same time become efficient at handling small and mid-sized standard inventory management projects.

The Environment

With a mission to solve current industry problems through applied research and offer the research benefits to students by providing a cutting edge educational experience, the lab opens up a window of opportunities that are both challenging and exciting. The major challenges facing the operations of the lab, identified during the first phase of the DE internship, are as follows:

Internal

- Evolving nature of knowledge base.
- Human resource constraints.
- Dearth of tactical skill set.
- Lack of proper information technology (IT) infrastructure.

External

- Increase in the number of projects and their uniqueness.
- Data integrity issues.
- Mix of hypo and hyper responsive clients.
- Technically unsophisticated end users.
- Customer scope creep.

Significant Needs

Given the above constraints, the lab has the following major requirements that need to be satisfied to increase its organizational effectiveness:

- Automate standard processes to reduce the time spent on non-value adding activities.
- Develop new and improve existing methodologies and quickly bring them from evolution to deployment.
- Use human resources effectively and efficiently.
- Creative solutions for data exchange and integrity problems.
- Minimize resource drain caused by customer scope creep requirements.

Internship Objectives

With the given mission, challenges, and needs of the lab, the overarching goal of my DE internship is to design and develop a framework for executing standard inventory management projects for future clients. The main objectives are as follows:

- Design and develop an operation-level inventory management project model that accounts for the complexity and uniqueness of each client w.r.t. organizational size, structure, management support, business processes, IT capabilities, etc.
- Leverage and enhance lab IT capabilities through design and development of software tools that will aid in quick data transmission, analysis and interpretation.
- Streamline lab operations to significantly reduce project life cycles and enable it to “do more with less” resources.

These objectives require a broad focus of people, technology and organization as a whole rather than a narrow view of specific problems. This will be evident in the following description of the nature of the internship experience.

Technical work

The core technical work directly relates to the topic area of production and inventory control in the industrial engineering discipline. It gives an excellent opportunity to implement and test theoretical inventory models related to the four modules given above. This requires a thorough understanding of the theory and its assumptions together with the ability to strike a balance between the theoretical essence, customer requirements and feasibility of implementation.

Communication

A significant portion of the time is spent on communicating various types of information. The intern position requires me to act as a common thread of communication across people in different roles and with different levels of technical knowledge. A typical example would be understanding clients' top management requirements, conveying and interpreting analysis results in their terminology, and convincing mid and low level employees to co-operate in implementation. Other types of communication include technical discussions, negotiating deadlines, interacting with laymen and IT personnel at client sites during business process mapping, etc.

Management

The lab employs a number of graduate students who work for research associates handling the projects. I have the responsibility to manage and/or co-manage one or more graduate students, which calls for management skills such as planning, assigning work, and supervising. This requires a fairly accurate assessment of the capabilities and motivational factors of each individual, evaluating the best person-job fit, setting realistic goals, and giving tactical guidance. These skills come into play even in relationship management during client interactions.

Strategy

Being a budding organization, the lab has the option to choose from several strategic directions. I have the chance to identify new opportunities and contribute to the development of a vision and a strategy to achieve it. This requires a fair understanding of the political and economic environmental setup of the lab.

IT systems design

The nature of work revolves around the IT systems and the people who use them both within the SCSL and at client locations. Methodologies, processes, and tools are finally implemented with the help of and in these systems. This needs a systematic approach to understanding the requirements, IT capabilities, end user sophistication, and performance measures. The design should take into account feasibility, scalability, flexibility, maintainability, usability and other such broad issues.

Approach

As can be seen, the internship experience requires contributions based on a holistic view of an organization and not just concerns with sub-system optimization. There is a need for taking a systems approach to solving the problems which will have an impact on the entire organization.

The internship work involves taking into consideration both the SCSL and the client organizations. It is primarily aimed at reforming the operations at the lab through people, technology, and environment together to better equip itself to strive towards its mission. In addition, the inventory project model as such looks at completely changing the perspectives at various levels of a client organization, and ultimately, the process by which inventory is managed.

The methodology and approach used to achieving the given objectives, a comparison of the same with theoretical approaches such as systems engineering and project management, the details of the contributions and the results obtained will be documented in the Record of Study.

Test cases

Two primary projects that I currently manage and in which the proposed inventory project model would be used are for Webb Distributors and Wilson Industries. In addition, projects for DealerTire Inc., JohnStone Supply Inc., and CH Briggs Hardware Inc. are other projects that would benefit from the work. The benefits derived using the approach from both the lab and the company perspectives will be documented and presented to the committee.

Contributions

An overview of some specific contributions made during the first phase of the internship is listed below. The details of the same will be given in the Record of Study.

Technical

- Developed an implementation version of the theoretical models for the above mentioned four modules.
- Established criteria for data definition, extraction, exchange and processing.
- Designed and developed an inventory management software tool (in MS Access and Excel) capable of handling real time client data that greatly reduced the processing time for analysis and results interpretation.
- Facilitated several technical discussions and helped evolve a knowledge base.

Non-technical

- Managed graduate students in developing software tools.
- Identified new opportunities with existing clients.
- Developed several data requirement templates to facilitate communication with clients' IT teams.
- Presented complex analysis results to clients in layman terms.
- Developed action plans and schedules for implementation of methodologies.
- Designed project deliverables and the processes to achieve them.

- Recommended plans to reduce lab overhead costs.
- Documented inventory management best practices in theory, implementation and how they match with processes in commercial ERP systems.

Summary

The first phase of the internship has given the opportunity to both exhibit and enhance my technical knowledge in the field of inventory management. In addition, I have had the opportunity to utilize my non-technical skills to contribute in addressing broadly based problems and in the process imbibed several important lessons not taught in classrooms.

I am confident that the nature of the internship work and the contributions meet the DE requirements of preparing an individual to function in a non-academic environment that encompasses both technical and non-technical fields. With the lab in a growth phase and set to handle a multitude of projects in the near future, it is my sincere hope that the internship efforts will lead to the creation of a strong knowledge base, maximize resource utilization, streamline operations and make a significant contribution of value for the SCSL.

APPENDIX E

INTERNSHIP SUPERVISOR'S FINAL REPORT

TEXAS A&M ENGINEERING
Department of Engineering Technology & Industrial Distribution

January 28, 2009

Doctor of Engineering Program
The Dwight Look of Engineering
Texas A&M University
College Station, Texas

The purpose of this letter is to provide a final evaluation of the internship project conducted by Sivakumar Sellamuthu at the Supply Chain Systems Laboratory (SCSL), Industrial Distribution Program,Texas A&M University. The internship objective was to design and develop automation tools to increase the lab's productivity and build operational inventory analysis models for practical implementation at client firms.

Sivakumar created a productivity tool in Microsoft Access and Excel for automation and standardization of data analysis processes. He identified several key business factors and data integrity issues that influence inventory analysis and decision-making in the real-world. His findings and recommendations led to streamlining of lab operations and significantly improved the practicality of solutions offered to clients.

During the internship, he effectively applied both his technical and managerial skills by taking a holistic approach to solving problems. Apart from exhibiting technical vigor while developing solutions, he accounted for several organizational factors such as human resources, information technology, administration, and project management. He clearly demonstrated the capability to function in a multi-tasking environment and communicated well with people from various backgrounds (business executives, technicians, analysts, graduate students).

In summary, the internship objectives were completely satisfied and the SCSL greatly benefitted from it. His contributions proved to be vital for the lab's exponential growth in the recent years and will continue to bear fruit in the coming years.

Walter W. Buchanan

Dr. Walter W. Buchanan,
Professor and Head,
Engineering Technology and Industrial Distribution

106 Fermier Hall • 3367 TAMU • College Station, Texas 77843-3367 • (979) 845-4951; FAX (979) 847-9396
http://etidweb.tamu.edu

VITA

Name: Sivakumar Sellamuthu

Address: Department of Industrial and Systems Engineering,
241 Zachry Engineering Research Center,
Texas A&M University, 3131 TAMU,
College Station, TX 77843-3131.

Email: siva@tamu.edu

Education: M.S., Industrial Engineering, Texas A&M University, USA, 2003
B.E., Mechanical Engineering, PSG College of Technology, India, 1999

Professional Summary:

- Nine years of industry experience in data-driven business process analyses and best practice implementation. Managed and co-managed several industry-funded projects.
- One of the founding members of the Supply Chain Systems Laboratory (http://supplychain.tamu.edu) at Texas A&M University.
- Areas of interest include supply chain management, inventory management, information technology, and pricing optimization.
- Ability to solve practical business problems by creatively adapting standard methods.
- Skilled at leading teams, managing client expectations, effective project planning, execution, and communication.
- Excellent perspicacity in understanding and connecting organizational strategy, operations, and technology.