Integrated Supply Chain and Inventory Management System at Raytheon

A Major Qualifying Project submitted to the Faculty of
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Submitted by:
Holly Cadran

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Report Submitted to:

Brian B. Bixbee, Program Manager
Raytheon Intelligence, Information and Services

Michael J. Ginzberg, PhD
Walter T. Towner, PhD
Worcester Polytechnic Institute

Abstract

The mission of the Trident Integrated Support Facility (ISF) is to ensure the United States Navy (USN) is fully equipped with operational, reliable guidance systems to support the Fleet Ballistic Missile program. The objective of this Major Qualifying Project (MQP) was to identify a strategic plan for migrating existing inventory management data from a highly manual, labor-intensive inventory control system to a predominantly automated system. The rationale for doing this project was to incorporate state of the art capabilities with respect to Material Resource Planning (MRP) to mitigate risk and improve processes. The methods utilized include, but are not limited to, observations and interviews, A3 problem solving, axiomatic design, testing and evaluation of various iterations, and various other industrial engineering concepts relating to optimizing system performance. Through collaborating across functional boundaries and synthesizing relevant project information, results concluded the Trident Program could more effectively manage inventory through leveraging the capabilities of a software system designed to house inventory data to allow for ease of management and program planning within a database as opposed to an Excel spreadsheet. A financial analysis of project implementation indicated that this system migration results in a Net Present Value (NPV) of approximately $240,000 and presents the opportunity to reduce labor requirements by approximately 500 hours and conserve an estimated $500,000 in labor costs over a 5-year period. This presents a reallocation opportunity for the Trident Logistics and Production Control team's resources to be used for tasking requiring more critical thinking and human involvement.

Acknowledgements

I am grateful for numerous indivuduals who contributed to the success of this Major Qualifying Project (MQP). In no particular order, thank you to my two project advisors, Professor Michael Ginzberg and Professor Walter Towner, for their instrumental guidance and insight. At Raytheon, I would also like to explicitly thank Brian Bixbee for assigning me to lead this project, Douglas Lada and the rest of the Kinaxis RapidResponse team, and the Logistics and Production Control team, specifically Ryan Gazlay and Kelly Singer. Finally, thank you to Raytheon Company in its entirety for affording me this invaluable professional development opportunity and unparalleled learning experience.

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Chapter 1: Introduction

Raytheon Company, in its entirety, takes pride in being a company comprised of "one global team creating trusted, innovative solutions to make the world a safer place" (Raytheon: Who We Are, 2018). Raytheon Company is a contractor most widely known and recognized for contributions in the defense industry, but Raytheon is also responsible many ventures within the civil government as well. Headquartered in Waltham, Massachusetts, Raytheon Company is comprised of over 64,000 employees worldwide and has been in existence since 1922.

Raytheon Intelligence, Information, and Services (IIS) is one of five of Raytheon's overarching businesses. Responsibilities of Intelligence, Information and Services include cybersecurity products and service, which can span from specific training to space, logistics and engineering solutions. These technical solutions can be provided to both government and civilian customers (Raytheon: Businesses, 2018). The United States Navy's (USN) Trident Fleet Ballistic Missile Program is one of the many customers of Raytheon IIS. On the Trident program, Raytheon IIS is contracted by Raytheon Space and Airborne Systems (SAS) to provide Level of Effort (LOE) support in addition to producrement of specific materials to support the manufacturing and testing of the guidance systems that are responsible for controlling the the Trident Fleet Ballistic Missiles.

Located in Pittsfield, MA is the consolidated Integrated Support Facility (ISF) where the assembly, test, and repair of these Trident inertial guidance systems takes place. In addition to the manufacturing and testing facility in Pittsfield, MA, there are various additional locations throughout the United States with personnel supporting this program from the USN, Draper, General Dynamics, and Raytheon. Both Burlington and Cambridge, Massachusetts are examples of alternate sites where Program Management support is currently located for the Trident Fleet Ballistic Missile Program.

1.1 Problem Statement

The guidance system responsible for controlling the trajectory of the Trident Fleet Ballistic Missiles is a complex, intricate system. These guidance systems also require routine maintence and updating. As a result, management of the material demands and transactions to sustain reliable fleet support requires a significant investment of human capital in addition to a system capable of executing complex forecasting calculations to produce actionable metrics. In providing the Navy with LOE and procurement support, Raytheon IIS is tasked with the management of what is known as the “Attrition Model”, which is the current mathematical model to be referenced as a baseline for material purchasing for future contract years. This baseline is then used to prepare a Bill of Materials (BOM) with specific quantites of parts to purchase for the coming contract(s). This purchasing projection process is applied to hundreds of parts, all of which have individual profiles. The current forecasting system has been referred to as the “Attrition Model.” The word attrition is in reference to parts that are not usable for production or compliant and within specifications, even after they are delivered onsite for use in manufacturing. This calculated rate of unacceptable parts versus acceptable parts per unit time, regardless of reason, is classified as an “attrition rate” for the specific part. The accuracy and integrity of this numeric value is imperative, as it can be used to project future purchasing amounts based upon expected rejection levels. Additionally, many of these parts reqire significant financial investment and present significant lead time to acquire, so a functional, reliable model is a necessity for robust planning. While having any quantity of non-complaiant material is undesirable to any program or business, that is unrealistic in most cases. The non-compliant data, though, can be leveraged to minimize risk and eliminate unnecessary costs. Collecting and analyzing data as it relates to individual parts and their performance enables a program to quantify reliability and plan accordingly.

Knowing the historical “attrition rate” of a part allows for a more holistic understanding of what to expect when material is delivered and enables program planners to determine a margin to adjust the material need to account for the expected non-compliant amount and ensure there is still sufficient material available. The current mathematical model utilized to integrate data is an effective means of housing necessary data sets and has numerous capabilities providing value for those involved in material management and program planning. However, this system is not as reliable as it could be, as technology has evolved beyond the capabilities of this Excel model. The exisiting system is heavily manual, as many systems are today, but this presents an opportunity for streamlining and automation. In automating such a complex, critical, and dynamic system, successful execution leads to reducing risk to the program, eliminating non-value added time in the administrative maintenance of the system, and minimizing overall cost. An opportunity to select and implement a more efficient, reliable, and streamlined inventory management and production planning system for the production of Trident Fleet Ballistic Missile guidance systems will be identified and the system will be transitioned.

1.2 Project Goals & Objectives

The goals of this project is to identify supply chain management software for use in integrated inventory management and implement the selected alternative for use in production planning to reduce risk, eliminate non-value added time, and minimize cost to the program. Through strategically implementing a series industrial engineering techniques relating to supply chain, lean manufacturing, and the flow of information and materials, I could analyze the current state of the inventory management system and construct a future state inventory management system to optimize resouces and ensure total system integration. This system integration is achieved through the identification and centralization of critical data sources, while still maintaining the ability to validate the integrity of the data if necessary. A current state value stream map is a lean manufacturing tool for the visualization and assessment of how information currently flows into and through the system, which is then followed by the generation of a future state value stream map to visually depict the desired flow of the future inventory management system as a whole and the interactions that will take place.

1.3 Project Deliverables

The project deliverables for this Major Qualifying Project (MQP) include developing and implementing an enhanced inventory management system and providing a visual, intuitive training manual to facilitate future use of the system beyond initial system deployment. In addition, a financial analysis of the resources saved will be conducted for further insight into reallocation potential of resources once the improved inventory management system is fully transitioned and functional.

1.4 Project Scope

The scope of this MQP is focused primarily in acting in the liaison role between the Logistics and Production Control (LPC) team and the software team to aid in system selection, implementation, and deployment through ensuring all technical, financial, and personnel aspects of the project are understood and effectively managed to ensure system success.

1.5 Project Timeline

The timeframe for completion of this MQP spans from initial launch in A-term of 2018 to project completion in C-term of 2019 (August 23rd, 2018 – March 1st, 2019). An Integrated Master Schedule (IMS) was used to visually depict, through a Gantt chart, the tasks and subtasks necessary to ensure a baseline to track actuals against. Due to the nature of the confidentiality of this project, the detailed Gantt chart cannot be included in this report.

Chapter 2: Background

2.1 Trident Fleet Ballistic Missile History

The Trident II D5 fleet ballistic missile (FBM) is an "intertial guided ballistic missile developed by Lockheed Martin" (Trident II D5 Fleet Ballistic Missile, 2017). The inertial guidance of the Lockheed Martin missile is the responsibility of Charles Stark Draper Laboratory (CSDL), which as of 2017, was allocated $58.6 million from officials of the Navy Strategic Systems Program (SSP) to upgrade this system to the Trident (D5) MK 6 guidance system and manufacture this improved system. This effort "includes failure verification, test, repair, and recertification of Trident MK 6 guidance system inertial measurement units (IMUs), electronic assemblies, and electronic modules" (Keller, 2017). Specificially, this aspect of the upgrading effort concerning failure verification, test, repair, and recertification is the area of interest of this MQP and the area in which integrated inventory management is of immense value to the program.

To expand, with respect to the guidance Trident (D5) MK 6 guidance system, the IMU has and continues to provide the sensing capabilities of the guidance system and the electronic assembly has and continues to act as the guidance system's flight computer recieving and interpreting these messages from the IMU and translating them into meaningful information. Essentially, the sequence of communication taking place as this guidance system initiates function is as follows: the IMU senses motion and direction of the missile, which it then relays to the electronics assembly, and this sensing information is then used as navigation information to verify that the missile is on target with the intended trajectory or to make corrections to the path of the missile if necessary. The Trident nuclear missile has extreme capabilities and is able to reach a maximum velocity of 13,000 miles per hour, has star sighting capabilities for navigation assessment, and has the impact of 475,000 tons of TNT, which is unfathomable in the sense that there is no historical event to compare this caliber of power to. This is the intent and the caliber of this missile is what allows it to remain a force that is respected in order to maintain maximum national security.

2.2 Axiomatic Design

Axiomatic Design, a method developed in the 1990's by MIT engineering professor, is a technique utilized when decomposing a problem in order to reduce complexity and simplify the overarching problem statement into individual actionable sections for analysis. Nam Pyo Suh, the MIT professor referenced above, proposed this systematic approach as a method of designing systems with specific stakeholders to effectively define system requirements and establish a method for documenting these requirements to ensure they are logical and met through the design process. There are two overarching, fundamental models that the method of Axiomatic Design is built upon. First, Axiomatic Design is based upon four design domain levels, which was created with the objective of generating an optimal design (Axiomatic Design, 2018). Figure 1, shown below, illustrates this notion in further detail.

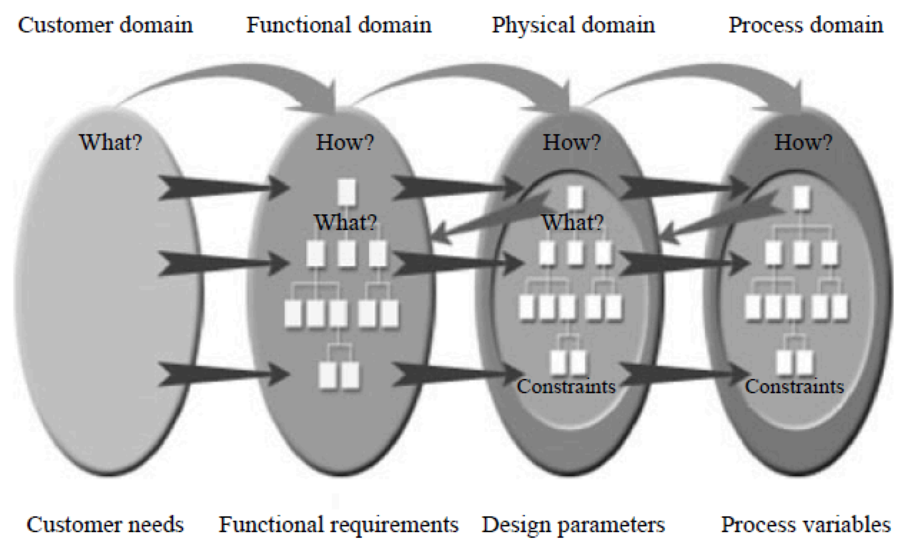

Figure 1: Axiomatic Design Process (Oxford University Press, 2001)

Second, there are two axioms, Axiom 1 and Axiom 2. Axiom 1 is the independence axiom, which maintains independence of the functional requirements (FRs). Axiom 2 is the information axiom, which minimizes information content to ensure successfully fulfilling the FRs and maximum simplicity in system design (Axiomatic Design, 2018). When developing and designing FRs, it is critical to ensure that they are both collectively exhaustive and mutually exclusive (CEME), solution neutral, and the parent FRs are equivalent to the sum of their children.

The relationship between the FRs and design parameters (DPs) is shown below in Figure 2. For each FR, there is a corresponding DP. The FR is what the system needs to do and the DP states how the system will achieve the specified need.

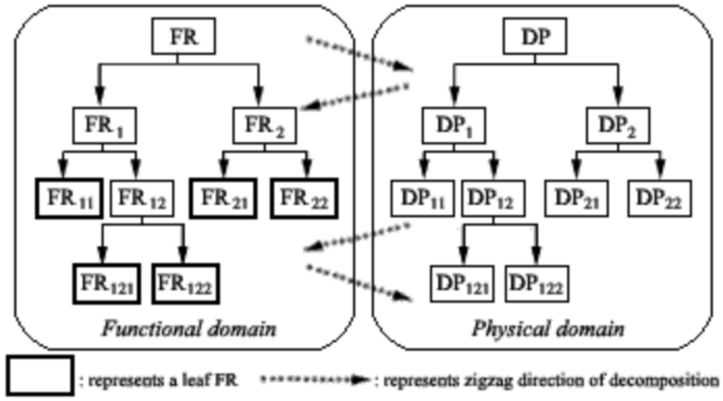

Figure 2: System Architecture – FR and DP Hierarchies (Oxford University Press, 2001)

The value proposition of Axiomatic Design is evident. The Axiomatic Design process is a powerful tool invaluable to the design process, as it leads those involved to make informed decisions, shorten design lead time, improve overall product quality, and manage complex systems.

Through leveraging Axiomatic Design capabilities in this project, significant benefit was realized as a result. The Axiomatic Design Matrix proved an invaluable resource in directly capturing the lower level DPs and FRs that stemming from their respective overarching high level DPs and FRs. The final system coupling matrix, strategically developed for an inventory management system, indicates the project outcome will result in an uncoupled system, meaning each DP can be independently changed without affecting more than one FR at one time.

2.3 Lean Manufacturing Tools

Lean manufacturing orginated in the Japanese vehicle manufacturing industry, as the production system Toyota adopted and implemented revolutionized manufacturing. Put simply, the theory of lean manufacturing is “to provide better quality of products with lower cost and on time with lesser efforts” (Modi, Thakkar, 2014). To any organization, this objective is desirable, as the objective of a business is to provide the highest quality product at the lowest cost in order to achieve the greatest return on investment of resources. Lean manufacturing tools account for a variety of approaches and theories regarding manufacturing, which can be applied to all systems where there is a raw material or information/data being converted into a final product of value to the customer. As they pertain to the scope of this project, a list of the most relevant lean manufacturing tools utilized include A3 problem solving, Key Performance Indicators (KPIs), Kaizen, and Value Stream Mapping to understand information flow in addition to material flow. Through effectively implementing tools such as those listed above, an organization is able to methodically and strategically quantify and understand the opportunity for improvement, which then leads to the development of a plan to address the challenge a given organization is facing.

2.4 Materials Resource Planning (MRP II)

According to Larry Giunipero, Material Resource Planning (MRP II) is an "approach to inventory planning, manufacturing scheduling, supplier scheduling," which "provides the user with information about timing (when to order) and quantity (how much to order), generates new orders, and reschedules existing orders as necessary to meet the changing requirements of customers and manufacturing" (Giunipero, 2014). In other words, MRP II is the second generation of MRP systems presenting enhanced capabilities for businesses to leverage enabling integration of both the external supply chain with internal production planning to achieve optimal effectivenss with respect to management of program inventory at any desired level. MRP II has an vast array of capabilities including the ability to create demand plans independent of production constraints as well as generating production plans that are a reflection of supply chain lead times (Lean Manufacturing Japan, 2008). According to Columbia's Guillermo Gallego, MRP II is an "integrated manufacturing system … additional functions of MRP II [compared to MRP I] include forecasting, demand management, rough-cut capacity planning (RCCP), and capacity requirement planning (CRP), scheduling dispatching rules" (Gallego, n.d.).

With respect to MRP II, many comparable existing software systems exist for businesses to evaluate to determine the most desriable system to fulfill project needs. It is critical in determining the most beneficial system that all viable systems are considered and their differences, advantages, and shortcomings are understood in order to make the most informed, objective decision. Current inventory and resource management systems available for industry use include Kinaxis, Ramco, SAP ERP, Oracle ERP, and Microsoft Access (ERP System, n.d.). These were the five primary systems considered for use with respect to the scope of this project. Conducting an analysis of alternatives allowed for tracebilitiy with respect to the decision on the system to use for Trident inventory management.

Chapter 3: Methodology

This chapter details how principles and tools from industrial engineering, specifically operations, supply chain, axiomatic design, and financial analysis were leveraged to transform an existing business process and create value for both Raytheon and the Trident program.

3.1 Problem Diagnosis/Decomposition

3.1.1 Axiomatic Design

The Bill of Material (BOM) is list generated based upon the raw data from the Attrition Model, which is then readjusted once the values are validated and finalized as a result of both Logistics and Production Control (LPC) and Program Management (PM) review. The BOM is dependent on the Attrition Model. The Attrition Model is currently used to determine the necessary parts to order based upon defined contractual requirements, historical profiles of parts, and the quantity of a part necessary per unit build. These values are then flowed to LPC and PM for final changes and validation, as mentioned above. Once the data is adjusted with Subject Matter Expert (SME) input, calculated quantities can be replaced with expert projections at the component level within the Attrition Model, if necessary. As a result, the quantity of each part expected for each respective Fiscal Year (FY) can be determined. Existing forecasts include expected values through FY21, but these values are based upon multiple variables and can be skewed heavily as a result of unexpected circumstances.

Due to the nature of any forecast, it is imperative to understand that all inventory data are dynamic and subject to change. With an unexpected change to the profile of a specific part, its rolling attrition rate will be impacted, which then affects the quantity of a particular part to order. In addition, the Attrition Model also generates, based upon the characteristic data detailed above, the approximate date the program is sustained through with respect to a given part. Based upon the level of outliers that can exist in these data sets, an expert review of each part profile and projection is conducted to achieve more robust BOM numbers. However, the data preparation process does not need to be manual, which presents an opportunity for process improvement. These values are critical, as accurate projections enable the program to meet and exceed the needs of a given contract and customer expectations, while inaccurate projections lead to a bottleneck in production and an inability to effectively meet program deadlines. Axiomatic design allows for these critical nuances in requirements to be captured and accounted for.

Appendix A and Appendix B reflect the Function Requirements (FRs), Design Parameters (DPs), and associated Axiomatic Design Matrix for the future state inventory management system. The Functional Requirements were developed in collaboration with all system stakeholders to ensure they accuractly reflect system requirements. More specifically, each of the four overarching FRs was further broken down into sub FRs, which each contribute to achieving the main FR they are listed under. As a result of explicitly detailing both high and low level system FRs, their respective DPs were also documented within the matrix, indicating how each FR will be realized.

3.2 Analysis of Alternatives

In an effort to select the most desirable solution for the customer, an analysis of viable alternatives was conducted. The following inventory management systems/databases were evaluated against various criteria: Kinaxis RapidResponse, Microsoft Access, SAP ERP, Ramco ERP, and Oracle ERP Cloud. Table 1 below illustrates mapping each system against the needs of the customer.

	Integrate Multiple Data Sources	**Government (& Navy) Approved**	**Cost**	**Material Resource Planning (MRP)**	**Ease of Training for User**
Kinaxis Rapid Response	Meets all needs of the customer	✓	Already invested	Forecasting, scheduling, and alerting capabilities	Raytheon has internal Subject Matter Experts
Microsoft Access	Meets most needs of the customer	✓	$150,000+	Database queries for scheduling	Many reference resources
SAP ERP	Yes, but doesn't interface w/ all	✓	Already invested	Enterprise Resource Planning	Specific training required
Ramco ERP	Lack of manual user input	Gov. Approved	Request Quote	Must be manually build by user	Not easy/intuitive to use intially
Oracle ERP Cloud	Meets all needs of the customer	Gov. Approved	Request Quote	Moderare MRP capabilities	Moderate ease of use

Table 1: Analysis of Inventory Management System Alternatives

Upon conducting this detailed analysis, it was determined that the Kinaxis RapidResponse system has capabilities most suitable for Trident's needs and the Navy has already approved the use of this system to support the Trident program. Additionally, the financial investment into both system licensing and intial system infrastructure has already been made, which is a factor to be considered in the assessment. The financial commitment is estimated to be approximately $1.7 million thus far in sunk costs, which presents an opportunity for recovery in achieving a favorable Return on Investment (ROI) through the potential benefits of the system.

In considering other system possibilities in detail, each alternative presented its own set of advantages, disadvantages, and unique capabilities. Microsoft Access was available through the Raytheon App Store, but it it is a desktop database and does not present cloud-computing capabilities. The system is not live and it would require additional financial investment to obtain user access as well as the investment of initial implementation. SAP ERP does not present all required channels to automatically flow data into the system and has limited customization capabilities, but it is currently used for managing and placing Purchase Orders (POs) on Trident. Ramco is a highly integrated inventory management system, but you cannot alter data easily, which is unfavorable, since Trident data often requires manual altering in specific cases. It is used in government applications, but reviews indicate is is not intuitive to use and requires significant investment in learning how to effectively use initially. Oracle ERP presents another alternative for implementation, but it has highly specific capabilities, which includes moderate MRP capabilities. As MRP functionality is the essential driver of the migration from the older, Excel-based system to the more advanced system, Oracle ERP does not prove as advantageous when considering comparable systems.

Kinaxis RapidResponse presents the most favorable range of capabilities for Trident inventory management. Some of the vast functions of the RapidResponse system include, but are not limited to, material production planning, forecasting, scheduling, automated alerting, and capacity planning (What it does: Concurrent Planning, 2018). With respect to specific functionality, "standard measures include revenue, margin, inventory value, on-time delivery and constraint utilization as well as metrics associated specifically with inventory planning and optimization" (Kinaxis, 2017). The user is also able to manually input and adjust data as needed in specified user tables, which is a priority to Trident, as there are many specific cases that may require human judgement and adjusting data. Additionally, Raytheon has Subject Matter Experts (SMEs) who can provide continuous support throughout implementation and testing of

RapidResponse as needed. This is an invaluable benefit to selecting RapidResponse as the software to proceed forward with, as there is existing infrastructure to support the transition as well as to provide operational support during post-deployment phases. Additionally, RapidResponse is in use at the Raytheon Enterprise level, indicating it provides value-added information and output to its users for decision making. Figure 3 below illustrates the unique value Kinaxis is able to provide to their customers through implementing a RapidResponse system, as the system is able to integrate both the objective functions of both the material planner and inventory planner into one holistic analysis.

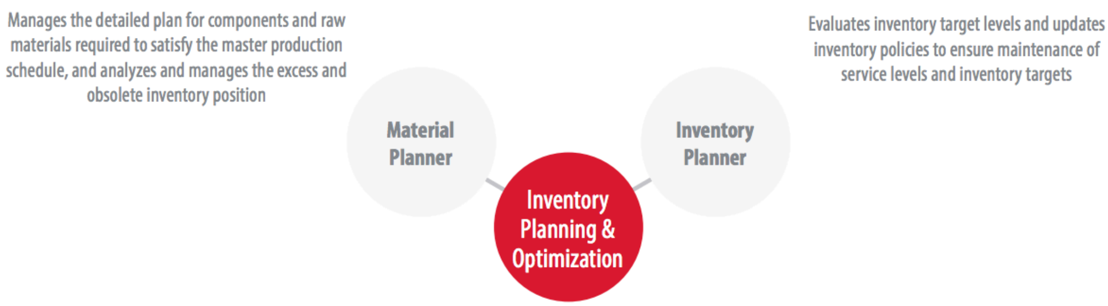

Figure 3: Kinaxis RapidResponse Value Proposition (Kinaxis, 2017)

There is an opportunity for Trident to cultivate significant value through leveraging the capabilities RapidResponse possesses, which includes the ability to generate custom reporting as well as a User Interface (UI) reflecting the needs of each specific user. Trident obtained multiple RapidResponse user licences and currently pays an annual licencing fee corresponding to these licences. These user licences have the ability to be allocated to the employees who will need to regularly interface with the system and users have the ability to customize the system to generate relevant metrics based upon individual roles. Following a detailed investigation and analysis of alternatives based upon specific, measurable criterion, it is evident that the Kinaxis RapidResponse system presents the most attractive set of capabilities and opportunity for ROI upon successful migration of inventory data. Upon this determination, system implementation is the subsequent phase within the project progression timeline.

3.3 System Implementation

System implementation is the process of defining how to both develop and implement an information system. The purpose of the system implementation phase of a project is to "construct system elements that meet the stakeholder requirements" (sebokwiki, 2012). In doing so, the objective is to ensure that the deployed system is both operational and usable from the perspective of the customer. During implementation of a system, this is priority. The implementation phase ensures that the system architecture correlates, as expected, to the functionality of the system, which requires consideration of several factors. Figure 4 below illustrates the system implementation process at the highest level, detailing the components that must be addressed in order to achieve the desired outputs such as implementation strategy and operator training.

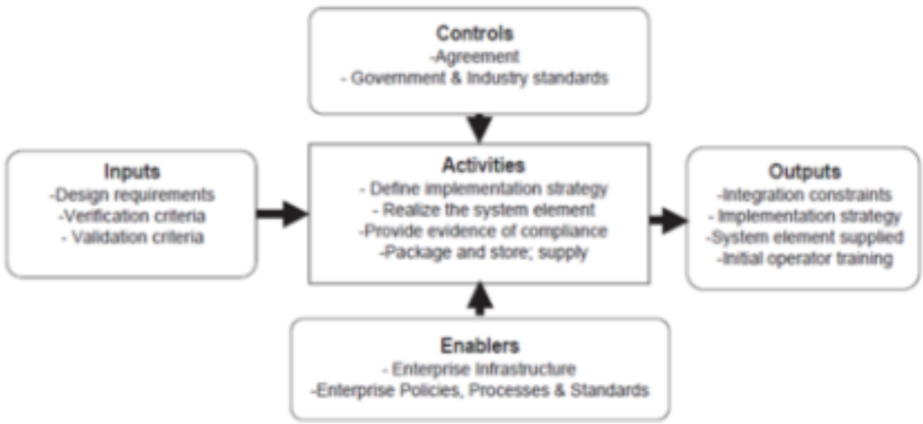

Figure 4: Context Diagram for the Implementation Process (sebokwiki, 2012)

In executing project goals, heightened attention to system implementation was an aspect pivotal to a successful project outcome, as it ensured verification and validation criteria were clear, processes and standards were followed, and requirements were followed.

3.4 Integration and System Testing

Upon meeting the system's individually defined requirements, it is essential that all of the indivdual aggregate components are able to be integrated into the overarching system of interest, as shown in Figure 5 below. Each of the implemented elements become aggregates, which then integrate to become the end product for the user. Through system integration, the project owner and team are able to oversee all aggregate components of a product coming together to become a functional system. Following this, the system must be tested for functionality throughout various phases of testing. Initial testing included functionality testing to ensure the system met requirements and was usable. Secondary testing entailed validation, which ensured the system was operating as expected in its intended environment.

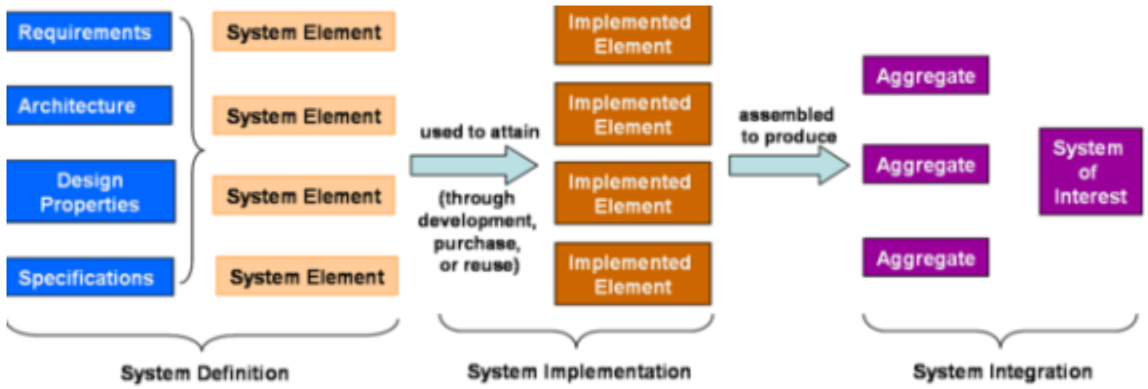

Figure 5: Overview of System Implementation and Integration (sebokwiki, 2012)

Through implementing these best practices of systems engineering and product development, there is a level of confidence associated with the final deliverable, as it has been reviewed through robust testing to ensure the product is operational and meets or exceeds customer needs.

Chapter 4: Results and Discussion

4.1 Analysis of Inventory Data

The inventory data was analyzed to understand critical data feeds necessary to output usable, insightful metrics for Trident program planning with respect to inventory and management of their supply chain. The resulting cloud-based system incorporates inventory data from numerous sources, all feeding into a centralized database with the ability to cyclicly pull necessary data, recognize the data, and direct it to its respective location within the system for use in analysis. Furthermore, the system possesses the ability to integrate and incorporate data entered by the user into detailed forecasts, which allows for hypothetical situations to be tested and assessed with respect to their impact on production. This is advantageous to the program, as it allows for those responsible for coordinating production efforts to understand the implications of their decisions and evaluate alternative outcomes against one another to determine the optimal solution with respect to cost, schedule, and quality.

4.2 Impact on Operations

This project is anticipated to have continued significant impact on existing operations because it streamlines the inventory management and facilitates program planning process through integrating inventory data into a centralized database. The migration of this data from being managed through a primarily manual, labor-intensive process to a highly automated, cloud-based system enables the user and the program to have increased confidence in the integrity of the output. This system output is directly utilized by those responsible for inventory and logistics management as decision-making metrics. Operations are expected to experience significant, measurable benefits as a result of this system implementation, which is favorable at both the functional group level and the program level in a greater context. Section 4.4, seen below, details projected estimates reflecting the value of this continuous improvement effort capturing the project value in its entirety.

4.3 Risk and Opportunity Management

The outcome of this project illustrates the value of promoting diligent and strategic risk and opportunity management within a program to ensure a culture of continuous improvement.

Though existing processes within a program may seem robust, reliable, and manageable, there are often gaps in technologies or other resources that may remain unseen unless personnel are trained to relentlessly look for and identify better ways of executing processes. This notion is essential for all global organizations to acknowledge and act upon in coming years, as it keeps businesses competitive and current. What often seems to be a small sub-process or simple responsibility of one employee may have the potential to be reinvented and revolutionized, leading an organization to various unforeseen benefits as a result of exploring and improving. Identifying risks within a program does not necessarily mean critical risks, but can also include risks that result in sunk costs, uncessary allocation of employee hours, and wasted time in general. These can be seen as a risk of wasting resources, but they can also be captured as an opportunity to recover costs mentioned above. Opportunities are means for a program to identify and create value.

4.4 Financial Analysis

The objective of a continuous improvement effort is to create value, through both making more effective use of resources to save time as well as cutting unnecessary costs, which streamlines processes and improves businesses. Through completing a project with potential to create significant value for an organization, it is essential to capture this economic value and quantify any gain. In the case of this MQP, factors considered include the elimination of predominantly manual labor to an increasingly automated system as well as an opportunity to streamline various subsequent efforts as a result of system integration.

Based upon recommendations, reduction of supply chain oversight, and inventory management efforts, it is expected that further streamlining the inventory management process for the Trident program presents an opportunity to conserve at least 500 labor hours annually, which can then be reallocated to supporting more complex tasking and efforts. In the span of 5 years, Trident can expect a savings of approximately $500,000 in both direct and indirect costs through utilizing this new system. This estimate is based upon the following assumptions stemming from company input:

- Each year reflecting a 10% increase in expected benefit as a result of overcoming the system's learning curve and generating compounding value
- Startup costs, including developing system infrastructure and migrating data, are included in the initial costs of year 0

- Estimated savings of $500,000 over a 5-year span due to reduced processing times and less user data maintainence

Additonally, another point to consider in conducting this financial analysis was the sunk cost of approximately $1.7 million dollars, which is not included in Figure 6 below, but has already been invested in the development of initial system infrastructure and maintainence of user licenses.

Assuming a 5-year analysis period and a zero-dollar salvage value of the system, this financial analysis captures the value of implementing this software system over its life cycle. Depreciation, which is a non-cash expense, is not included when applying the PV method. Additionally, one time costs were considered and facored into the analysis, shown in year 0, to reflect the investment of maintaining user licenses as well as necessary resources to migrate data and develop system functionality and infastructure. Based upon this financial analysis, the Net Present Value (NPV) of this project is estimated to be approximately $240,000, which accounts for all captured cash flows converted to the present and an assumed 10% interest rate, which is commonly used in assessing the NPV of many projects.

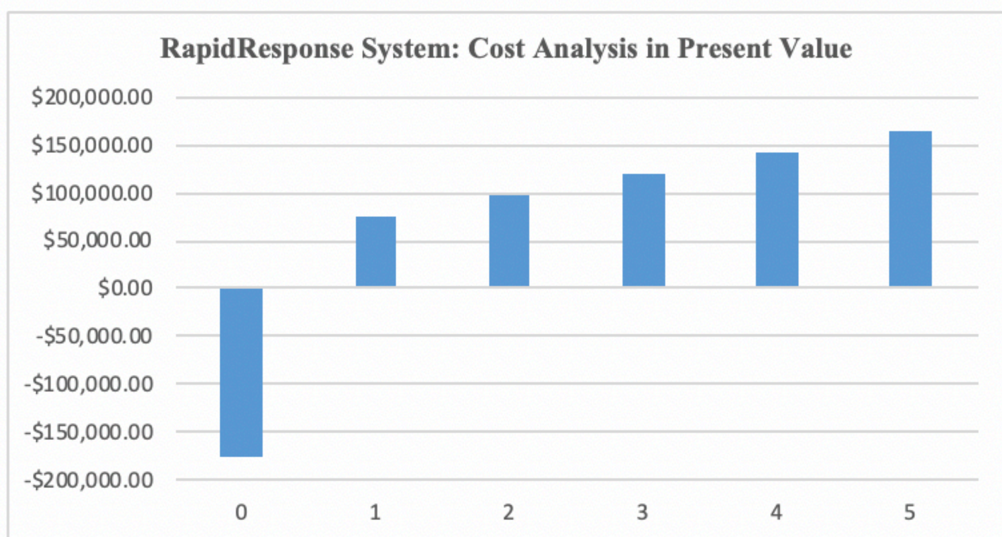

Figure 6: Financial Analysis of RapidResponse System

Based upon the financial analysis, it is evident that the transition from the previous inventory management system to RapidReponse is favorable, not only with respect to risk mitigation and remaining technologically current, but also from a financial perspective. Through conducting this detailed financial analysis in Excel, the persuit of implementing this system is further justified.

Chapter 5: Recommendations

5.1 Enhanced Materials Resource Planning (MRP) System

The first recommendation is to continue to utilize the newly implemented RapidResponse system. This may seem obvious, but it is not uncommon for continuous improvement efforts to become negated once implemented if the momentum to continue to utilize a system is not actively maintained. The enhanced system proves valuable in numerous ways and this value must continue to be leveraged to achieve maximum effectiveness in supply chain management and production planning.

5.2 Standardization - Employee Training Manual

Standardization is an essential component to successful system deployment and integration. Following the successful implementation, a necessity to ensure the system continues to be a value-added tool for program planning and forecasting is developing a method to capture system features and tutorials regarding system use. In the case of the Trident program, standardization of training documentation for this new inventory management system ensures the information is accessable as opposed to the knowledge residing in the minds of the Subject Matter Experts (SMEs). A detailed training module, in the form of a PowerPoint file with the option of complementary video tutorials, shall be developed as a method to allow for holistic information flow as employees leave and new employees are hired to manage inventory.

5.3 Expanding Risk Management

The final recommendation following system implementation is expanding risk management. In general, it is imperative for any organization to be continually identifying and assessing risks, determining probabilities of risk occurances, and identifying methods for mitigating these risks. In doing so, the management within organziations must seek input across all skillsets, experience levels, and job titles to obtain insight necessary for effectively implementing risk management at all levels. Diligent risk management at the lowest organizational level through soliciting input from individual contributors will enable risk to be minimized, as the smallest details will be accounted for, which increases overall confidence from the customer perspective.

Chapter 6: Conclusion

This project presented invaluable opportunity for me to grow in the skillset of managing project execution while working across an array of functional disciplines. The management of people, as well as their motives, skills, and personalities, to work towards a common vision to accomplish an end goal was the true challenge while working on this project. Consequently, this is also where the most growth occurred for me. Completing this project has effectively shown me the countless challenges associated with the execution of a real technical project. What was counterintuitive, though, is that the aspects of the project that originally appeared to be the most challenging aspects to overcome were actually not the obstacles hindering progress.

Change management is an essential component to successfully driving businesses forward technologically across the world today. Effective change management is a multifaceted skill, which stems from the ability to understand, lead, and implement changes that are often times met with an array of resistance from both personnel and unforeseen obstacles. The concept of change management can be defined as the ability to “prepare, equip and support individuals to successfully adopt change in order to drive organizational success and outcomes” (Prosci, n.d.). This project presented the opportunity for me to obtain both experience and a substantial list of lessons learned with respect to the way migrating from the old to the new is often received across a team, its respective program, and the business unit as a whole. Change management requires significant attention to people, requirements, and adhering to an implementation plan with detailed milestones.

To elaborate further, generational gaps become vastly apparent with respect to willingness to adopt change. In my experience, younger or less experienced generations are more readily open to accepting change as well as being a proponent of finding ways to improve existing systems to achieve optimal performance and resource allocation. This open-mindedness is likely a result of the younger or less experienced generations being accustomed to frequently adapting to the rapid changes in technology that have occurred over their lifetimes and being more comfortable of said developments. However, often times, the more senior generations met such enthusiasm for change with a list of associated potential challenges and distaste for transitioning to something new when the existing system “worked”. Change can be good, change always presents opportunity for growth, but change is difficult and must be strategically managed. As an industrial engineer, ownership of this statement is my job. It wasn’t long into this project before I realized the idea of powerful change management was going to be the most important aspect of the project that would determine whether we achieved successful implementation or it was discarded as "just another big idea" by those with more company experience than myself.

In the same respect, it is the responsibility of all employees, especially those looking to lead and advance their careers, to be diligent in remaining current on technological developments, best business practices, and any news as it pertains to the direction of the business as a whole. This is how to become a leader who understands the greater context of a business problem, which allows for the application of this understanding to inspire those within a team to realize the significance of a challenge at hand and find purpose in working on a solution. This was something I learned in my experience working across functions, backgrounds, and personalities on this project. Working within a vacuum is not the approach to successfully leading and inspiring change within those around you.

Working across an array of functional boundaries, geographical locations, and distinct personalities presented the one of the most significant challenges in project execution, which was not originally foreseen as a potential obstacle in project progress. This project required I work seamlessly across software, logistics, supply chain, engineering, and program management functional areas, all presenting their own respective concerns, terminology, and specified knowledge, which frequently did not effortlessly converge. For example, those within the software group often did not understand the intricate needs of the logistics group users, whereas those in the logistics group encountered challenges communicating their system requirements to the software group to develop. This is where my role had value and this is where I learned. It was the completion of this project that solidified the notion that everyone has a different approach to dialogues, meetings, and other communications. As a result, the understanding of how to best approach an interaction with a given project member is the hallmark to successful development and deployment of any solution within a team. In my experience, I found that some people prefer direct, efficient communication with minimal excess information, whereas others may need to understand the entire problem, how their role has significance, and be reminded of the value of their contributions in order to stay motivated. This was an unexpected, but invaluable, revelation. The ability to understand people, what motivates them, and how to recognize and harness their value is an area of growth I found to be the most profound in my work.

Through my interdisciplinary liaison role leading this project to completion, I also discovered the challenges associated with residing in a role that presents significant responsibility with minimal authority. It was a privilege to be entrusted with a project of this caliber at such an early point in my career, but I was also exposed to how young and less experienced, fast-paced individuals can sometimes be perceived by those around them who feel they may not be qualified to provide direction and assign deadlines. The majority of challenge with authority in this role undoubtedly comes with the title of "intern," but identifying personal methods of effectively asserting authority is still an experience to note as an early career individual with vast career aspirations, since this will be a recurring theme throughout my career. This project provided me with the visibility to learn that there are employees who will require more direct, frequent oversight to ensure job is getting done, despite what is being reported verbally. Increased individual oversight can take on the form of a meeting with all stakeholders to ensure all members are on the same page, Skype meetings to review specific, actionable details with the person responsible presenting and explaining their work, or transparent routine updates if the employee responds well to such direct oversight. Relying on and trusting others at varying levels, based upon past performance, is something I found to be the most challenging throughout the duration of this project. It is imperative, as the lead of a project, program, or company, to identify within the early phases of a project those who can be trusted with minimal oversight, those who need routine direction to remain motivated, and those who must be more closely monitored to ensure milestones are being met – all in a respectful, gracious way. This has little to do with the technological components of the project, and again, everything to do with the people.

This project afforded me the opportunity to gain exposure to countless invaluable lessons some may not learn until the middle of their careers, if at all. I have grown immensely, both professionally and personally, as a result, which has made me a more influential industrial engineer overall. I learned that a leader is often not a result of a job title, but it is a result of those who empower those around them and create an environment for collaboration. Migrating an Excel-based inventory management system to an advanced inventory planning and forecasting software system has allowed me to take a business opportunity at the lowest, most micro level and apply that learning at a macro scale to understand how these challenges and opportunities for improvement impact an organization at the highest, most senior level. From a liaison/consultant perspective, as leaders continue to be responsible for driving organizations forward, it is critical that they relentlessly identify and pursue areas where resource allocation can be improved with the intent of realizing the greatest possible Return on Investment (ROI) of said resources. A leader must be diligent in inspiring and those around them with a compelling vision, facilitate the development and deployment of smart solutions, and maintain momentum throughout the duration of the project at hand. Organizational leaders must maintain a balance between investing themselves in understanding and managing the details, while also engaging in high-level thinking to ensure business ventures are in alignment with organizational values, goals, and vision.

Appendicies

Appendix A: Functional Requirements and Design Parameters for Axiomatic Design

#	[FR] Functional Requirements	[DP] Design Parameters
0	Forecast production demand for manufacturing system	System for forecasting production demand for manufacturing system
1	System shall integrate forecasting inputs from multiple sources	Database for integrating forecasting inputs from multiple sources
1.1	System shall house delivery schedule from the customer	Method for housing delivery schedule from the customer
1.2	System shall house inventory purchasing data	Method for housing inventory purchasing data
1.3	System shall interface with existing inventory disposition database	Process for interfacing with existing inventory disposition database
1.4	System shall tabulate data	Method for tabulating data
2	System shall generate detailed reports to facilitate decision making	Method for generating detailed reports to facilitate decision making
2.1	System shall be capable Material Requirements Planning (MRP)	Mechanism for Material Requirements Planning (MRP)
2.2	System shall have customizable interfaces based upon **user**	Method for customizing interfaces based upon **user**
3	System shall process inventory data to produce forecast	System for processing inventory data to produce forecast
3.1	System shall have a limited, customizable **user** access list	Method for limiting/customizing **user** access list
3.2	System shall allow override of integrated data by designated users	Method for overriding integrated data by designated users
4	System shall automatically notify users of inventory status	Procedure for automating system responses to specified users
4.1	System shall be able to perform mathematical calculations	Method for performing mathematical calculations
4.2	System shall be able to utilize calculated outputs for inventory forecasting	Mechanism for utilizing calculated outputs for inventory forecasting

Appendix B: Axiomatic Design Matrix

	DP0: System for forecasting production demand for mar	DP1: Database for integrating forecasting inputs fron	DP1.1: Method for housing delivery schedule for	DP1.2: Method for housing inventory purchasing	DP1.3: Process for interfacing with existing inven	DP1.4: Method for tabulating data	DP2: Method for generating detailed reports to facilit	DP2.1: Mechanism for Material Requirements Pl	DP2.2: Method for customizing interfaces based	DP3: System for processing inventory data to produc	DP3.1: Method for limiting/customizing user acce	DP3.2: Method for overriding integrated data by c	DP4: Procedure for automating system responses to	DP4.1: Method for performing mathematical calc	DP4.2: Mechanism for utilizing calculated outputs
FR0: Forecast production demand for manufacturing system	O														
FR1: System shall integrate forecasting inputs from multipl		X					O	O	O	O	O	O	O	O	O
FR1.1: System shall house delivery schedule from the c			X	O	O	O	O	O	O	O	O	O	O	O	O
FR1.2: System shall house inventory purchasing data			O	X	O	O	O	O	O	O	O	O	O	O	O
FR1.3: System shall interface with existing inventory dis			O	O	X	O	O	O	O	O	O	O	O	O	O
FR1.4: System shall tabulate data			O	O	O	X	O	O	O	O	O	O	O	O	O
FR2: System shall generate detailed reports to facilitate dec		O	O	O	O	O	X			O	O	O	O	O	O
FR2.1: System shall be capable Material Requirements		O	O	O	O	O		X	O	O	O	O	O	O	O
FR2.2: System shall have customizable interfaces base		O	O	O	O	O		O	X	O	O	O	O	O	O
FR3: System shall process inventory data to produce foreca		O	O	O	O	O	O	O	O	X			O	O	O
FR3.1: System shall have a limited, customizable user a		O	O	O	O	O	O	O	O		X	O	O	O	O
FR3.2: System shall allow override of integrated data by		O	O	O	O	O	O	O	O		O	X	O	O	O
FR4: System shall automatically notify users of inventory sta		O	O	O	O	O	O	O	O	O	O	O	X		
FR4.1: System shall be able to perform mathematical ca		O	O	O	O	O	O	O	O	O	O	O		X	O
FR4.2: System shall be able to utilize calculated outputs		O	O	O	O	O	O	O	O	O	O	O		O	X

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