Lean Process Improvement at Mack Molding

Major Qualifying Project Submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE

In Partial Fulfillment of the Requirements for the Degree of Bachelor of Science

February 14, 2017

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ABSTRACT

The main objective of this Major Qualifying Project was to evaluate and update the design of a product launch tracker at our sponsor, Mack Molding. The methods used to achieve our goal were Axiomatic Design, research of management and implementation tools, employee insight, stochastic modeling and an engineering financial analysis. Through these methods it was identified that the tracker could be designed into a hybrid of both a phase gate and milestone tracker, to create an accurate forecasting tool. It is recommended the updated phase tracker for reducing non-value added time in the launch process and rework of tools. The feasibility of the tracker was studied through an engineering economic analysis that displayed the savings that would be achieved over a two-year period.

ACKNOWLEDGEMENTS

Our team would like to acknowledge those who have contributed in enormous ways to the success of our project.

To our sponsor Mack Molding, we thank you for giving us this opportunity to have a real- world experience, learn about your company and gain invaluable lessons, which we can take with us into our careers. We would especially like to thank Dwalin DeBoer, fellow graduate of WPI, main contact at Mack, and without whom this project would not have been complete. Your constant willingness to provide us with as much information as we needed at any point in time and your eagerness to help us succeed is truly appreciated.

Next, we would like to thank our faculty advisors, Walter Towner and Helen Vassallo. Your guidance and advice have been crucial to our success and we are ever grateful for the confidence you had in us and the wealth of knowledge you have given that will benefit us far beyond the scope of our project.

Finally, we would like to thank Worcester Polytechnic Institute and the Foisie School of Business for giving us this unique opportunity to transform what we have learned in theory to a truly practical application. This is something that we will undoubtedly take with us as we embark in our careers.

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1.0 INTRODUCTION

Mack Group Corporation is a contract manufacturing company focusing primarily on manufacturing services and plastic injection molded parts. Mack Group's services span across a wide variety of industries ranging from commercial products to medical devices. The company is composed of various entities organized into five different companies including: Mack Molding, Mack Technologies, Mack Prototype, MackMedical, and Synthetic Engineering Services. Mack Group has over 11 locations across the United States expanding to a total of 1.5 million square feet of manufacturing space with their headquarters shown in Figure 1.

Figure 1: Mack Molding

Mack Molding, headquartered in Arlington, Vermont, provides injection molding and contract manufacturing services, ranging from design and development services, prototyping, injection molding, finishing services, and sheet metal fabrication. The company offers services to medical, commercial, computer & business equipment, energy, and transportation markets. Mack Molding has locations in Vermont as well as its southern locations in South Carolina and North Carolina, which focus on larger scale molding, in comparison to the northern locations. Mack Molding delivers high quality results through their combination of sales and engineering in every project to provide each customer with the assistance to successfully develop and complete the production of any product in any stage (Naitove, 2012).

1.1 Problem Statement

Mack Molding is a leading supplier of molded plastic parts, fabricated metal parts and high-level assemblies to the medical industrial, transportation, and energy/environment industries. Mack Molding works with a wide range of companies, each with its own customized order and process. Like many other contract manufacturing companies, Mack utilizes a project management tool known as a phase gate tracker. Currently, Mack has reported an underutilization of their current Phase Gate Tracker, which can assist with accurate benchmarking, process analysis, and project planning. The current phase gate process lacks a standardized process that fits with the needs of the employees trying to achieve a successful product launch. The underutilization of the tool has led to disconnection between departments regarding communication among the project team. Mack Molding has sponsored this MQP with Worcester Polytechnic Institute. The team worked to develop a new, improved phase gate process through a series of process flow analyses accompanied with lean manufacturing applications. Process improvements within the organization were made with the development of the new Phase Gate Tracker and allow for improved visibility within the organization across departments regarding the role of each individual and project team.

1.2 Project Goals

1. Understand the current phase gate review process and the responsibilities of individual departments
2. Assess the needs and requirements of each department
3. Conduct a process flow analysis of the phase gate review process and sub processes
4. Determine the appropriate modifications in relation to the development of the Phase Gate Tracker
5. Integrate the Phase Gate Tracker into the organization through training and providing training materials for the future
6. Make recommendations for future continuous improvement within their product launch process

1.3 Project Deliverables

The following items were delivered:

1. New Phase Gate Tracker: Microsoft Excel Project Management Tool
2. Phase Gate Tracker User Guide with Slide Deck
3. Recommendations for continuous improvements

4. Financial Analysis

1.4 Project Scope

Mack Molding's current phase gate review processes as well as the needs of the departments involved were examined and a new Phase Gate Tracker was modified and developed in replacement of their underutilized, current tool in place. The Phase Gate Tracker is a tool developed using Microsoft Excel with various tabs to encompass the entire product launch process. Various departments and essential tasks involved in the process were analyzed as well as each departments involvement in each stage to successfully deliver a tool that can be utilized by each project team.

2.0 BACKGROUND

2.1 History of Mack Molding

Donald S. Kendall and Kenneth W. Macksey founded Mack Molding in 1920. The company started out in Little Falls New Jersey but quickly expanded to Wayne, N.J. and Arlington, VT Mack Molding originally began manufacturing bottle caps and other retail products and soon transitioned their manufacturing production towards assisting war efforts. Mack Molding's manufacturing production increased to serve the war effort, by switching production to mortar-shell casings and other WW II tools.

Mack Molding grew obtaining various partners and clientele. Mack expanded into manufacturing consumer products such as Timex watch boxes and Schick razor handles. Production commenced of plastic computer monitor housing for IBM, starting a transition into the computer and business equipment industry. Today, Mack ranks among the top 10 non-automotive molders in North America, and supplies plastic and metal parts/assemblies to numerous essential markets (Naitove, 2012).

2.2 Phase Gate Review Process

Mack Molding frequently launches new products with various companies; therefore, an effective project management tool was needed. Currently, Mack Molding utilized a phase gate tracker tool to monitor the progress of their projects. The phase gate review process is commonly referred to as a stage gate checkpoint strategy and acts as a tracker and checklist for successfully adhering to a specific method (J. C. Grzinich, 1997). A phase gate process is comprised of a series of steps representing essential activities in a process. As shown in Figure 2, these 'phases' are then separated by gates which act as indicators for

a certain phase of a project to continue or not dependent on the level of completion of the various tasks and level of risk (J. C. Grzinich, 1997). This type of project management strategy is often used in industries where product launches are occurring regularly. Developing a standardized process that is documented and visible to an entire organization can harvest a collaborative, innovative environment. A phase gate process can eliminate risk earlier on in a project and bring any potential issues to the forefront of any project. In an article regarding product development and the stage gate process, the author states, "Stage-Gate methodologies are recognized and widely embraced in companies all over the world as a method of bringing order to the sometimes-chaotic process of product innovation. After surveying NPD, best practices, Griffin noted that 60% of responding NPD functions were using some form of Stage-Gate methodology" (Grönlund, 2010). The phase gate process is increasingly becoming more popular in successful companies and can be adapted to adhere to a company's specific strategies and goals. Mack Molding may succeed with a modified version of their current phase gate process in order to increase the flexibility of each milestone in the process (Grönlund, 2010).

2.3 Process Flow Analysis

A process flow analysis is a method often used to better understand the current state of any

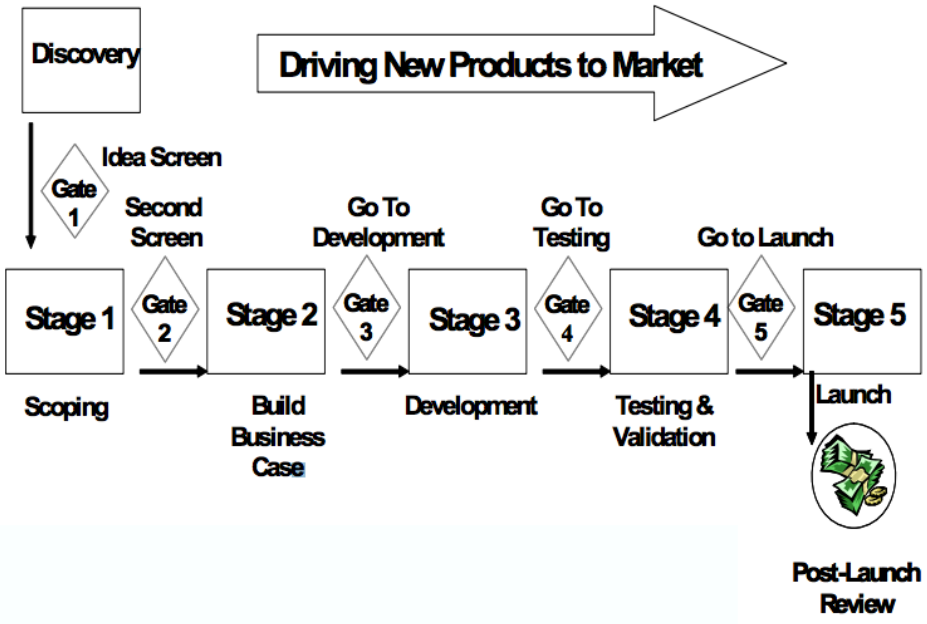

Figure 2:Example of a Phase Gate Model

(Source: Cooper, 2002)

process. Different environments in which this type of analysis is used can have various effects, such as resolve differences and bring groups together. The major use of a process flow analysis for this project was to help create a clear and concise image of the process flow, which ideally led to a tangible change within the process itself. In composing a process flow diagram, one can identify the non- value added components of the process and highlight crucial points of connection and flow. In many processes, there are aspects that are imperative to its progression and without them the process will come to a stop. While creating the diagram, different shapes are used to differentiate from these 'check points'. This process flow can also be used as a guide that a company follows to reduce the amount of variance between employees and departments. Without a process flow, a company risks discontinuity in their process. In order to succeed in the development of the tracker, a process flow has to be done at Mack (Jacobs and Richard, 2010).

2.4 Communication Flow Analysis

A communication flow is a network of employees in which information and knowledge are communicated to complete certain tasks for the overall goals of the company or department. The flow needs to have an efficient communication network amongst employees to achieve high performance. In most cases, there are either too many employees inputting information into a system or not enough employee involvement in the system. With having too much involvement, employees begin to lose focus on who should be contacted about the information, adding "dead time" to different sections of the network with unnecessary communication. On the other hand, if there are minimal employees in the system, critical information can be miscommunicated to important employees involved in the process. "The Project management communications toolkit" emphasizes the need for effective communication in the workplace. It is evident that further issues will be created further down the work stream if lack of communication is present. The key for a company is to find a balance between these two issues in order to find an optimum communication and transparency across the company (Pritchard, 2014).

2.5 Accepting Change in the Workplace

Procedural and organizational changes within a company are becoming increasingly more common in the new digitalized world. With continuous change, employees have been forced to become more flexible and open to changes within their role in an organization. As a result, some companies face the issues of resistance to change or to new ideas within their organization. Numerous studies such as a case study by the Journal of Information Technology in the U.K. and a study in the International Journal

of Human Resource Management have been conducted to fully understand the root cause regarding an individual's lack of acceptance to change specifically in the workforce (Serafeimidis and Smithson, 2000; Iverson, 1996). For example, an employee may feel vulnerable to stepping outside of their normal routine or do not fully understand the reason for a specific change. The management team must take appropriate measures to provide their employees with a complete understanding of a specific change being made in order to successfully implement that specific change (Creasey, 2014).

When implementing a new standardized process or tool into an employee's role, there are many steps to focus on throughout an implementation or a process change. In a journal, "Seven Greatest Contributors to Change Management Success," Creasy outlines specific steps and strategies to implementing change in a professional environment. Oftentimes, an employee will be hesitant to change their routine thus becoming resistant to change. The idea of resistance to accept change within the workforce may affect an organization's ability to continuously improve. Therefore, the importance of taking preventative actions when implementing change in a workforce environment must be considered. It is essential to understand an employee's feelings towards their hesitation to not fully accept a change in order to develop a clear line of communication throughout implementation. A small change creates an uneasiness in most people, simply because their standard thinking has been changed and time is needed to adjust. This is where management must create a better user experience to encompass the issue of employee's fear to change (Creasey, 2014).

Management must effectively implement change by understanding the employee's point of view. Research has shown that three strategies management can employ are; to provide exact information about the change in tasks for the employee, keep employees involved in the process change, and reassure the employee's that they will be able to gain the additional skills needed to complete the task. Management needs to be transparent about the change by providing information to the employees. This can be done through providing advance information about the change and clarify why the changes are being made to the specific employees. Also, management should anticipate questions about the change and should answer them to the best of their ability. Lastly, managers should provide employees time to reflect on the changes and allow for a period of adjustment. This adjustment period would allow less stress on performance and more on perfecting the new process, which would lead to increased performance (Wanberg, 2000).

Another strategy to implement is keeping the employee involved in the process change. This participation can indirectly increase the employee's knowledge of the process and lessen fear. Improving a process can be complex and challenging, so if the employee's knowledge is involved in this tough situation, it allows them to feel important and take ownership of the process. This leads to better adaption of a more user friendly model. The last strategy that can be implemented is reinforcing that the employee can gain the additional skills to perform well with the new operation or process. This can be reassured through providing adequate and complete training. Also, reassurance of no punishment from performance level drops due to learning the new process. In a journal article," Predictors and outcomes of openness to changes in a reorganizing workplace," a study was performed to study the different variables that affect an individual's willingness to change. The study encompassed the idea that an individual's willingness to change was directly associated with how he or she felt. Overall, fear of adaption is prominent in industry, but the way it is handled is the deciding factor. If a manager is able to involve the affected employee in the process of change and stays transparent at each phase; then fear of change can be reduced and positive results can be achieved (Wanberg, 2000).

2.6 Axiomatic Design

Axiomatic Design has been applied to manufacturing system design yields on numerous occasions. It focuses on the sub-components of the manufacturing system design, resulting in the proposed procedure being sound, comprehensible and easy to implement (Kulak et al. 2005). The key principle of Axiomatic Design is that a decomposition approach can be used to explain, understand, replicate and deploy the manufacturing system. It develops a general framework of requirements for success. This augments the design and development of innovative and effective manufacturing systems that transcend the company's current benchmarks (Won et al. 2001).

Developed by MIT's Nam Suh, it is a methodology that uses decision matrixes to systematically analyze customer needs and convert them into functional requirements (FR), design parameters (DP), and process variables (PV).

- Functional Requirements are variables that characterize the design and purpose of the system.
- Design Parameters are variables that describe the design and function of the system.
- Process Variables are variables that characterize the design in the process-manufacturing domain.

Management principles coupled with Suh's Axiomatic Design are used to identify and improve the tracker at Mack. Using these constructive variables, Mack's requirements were analyzed to form several alternative solutions. Establishing Functional Requirements helped express the desired system's purpose. The Design Parameters are the necessary variables selected to achieve this desired system and are created and attempted after extensive analysis (Suh, 1990).

3.0 METHODS

3.1 Analysis of Phase Gate Review Process

3.1.1 PHASE GATE TRACKER

The core idea behind the phase gate review process is to track the status of a product from beginning to end to ensure consistency and accountability throughout the company. As previously stated, the current tracker was not being utilized to its full potential therefore the people involved in each process created their own method. This creates an inconsistency from one project to another and creates more work for the Project Managers (PMs), as well as the other departments who have to cater to the ways of each PM. In order to create a standardized process and increase utilization of the Phase Gate Tracker across the company, the tool will require some rework and adjustments to suit the needs of the users.

The Phase Gate Tracker currently includes their entire list of tasks that are required during the four phases of their product launch process. Every task belongs to a specific phase of product launch and is accompanied with a specific owner (department) as well as a specific status. For example, if a task is complete, the owner/department is documenting the task is complete within the appropriate section. In addition, the Phase Gate Tracker tool includes four different phases that are separated by gates. Ideally, the gates act as indicators for the team that a phase is complete through a signature indicating the next phase may begin.

Mack Molding would like to take their current Phase Gate Tracker and product launch process to the next level increasing user friendliness of the tool and improving relevancy of the tool in relation to the current process. In addition to the modifications of the tool, Mack Molding would like to use the new tool to develop an increased understanding of a standardized process that needs to be followed by each project team within the organization.

3.1.2 PROCESS FLOW

In order to modify the Phase Gate Tracker, a process flow diagram is needed in order to gain a more complete understanding of how the Phase Gate Tracker could be improved. An in-depth outline regarding the steps taken from receiving a new product opportunity, entering validation and finally moving to actual production was first outlined, then the internal steps Mack took to get through the process was documented. Understanding the flow of Mack's process is an instrumental aspect of editing the new tracker. With a clear and accurate process flow, the right components of the tracker can be effectively targeted and updated (Jacobs and Richard, 2010).

Currently, Mack has a documented process flow that varies depending on what type of product is being made. Because of their wide range of services, the production can shift from highly complex parts with extreme validation standards, to a simple product with loose metrics. When looking into the formation of a standardized tracker, the idea that the process is constantly varying needs to be taken into account. The basic flow of processes will be followed and adaptations will be made as necessary. The current process flow of Mack Molding's product launch process can be seen in Figure 3: Mack Molding's Phase Gate Review Process Flow. This process flow diagram demonstrates the current process and allows for identification of areas of improvement. It is color coordinated to reflect the efficiency of the various stages, green being effective and red signaling where the tracker is ineffective.

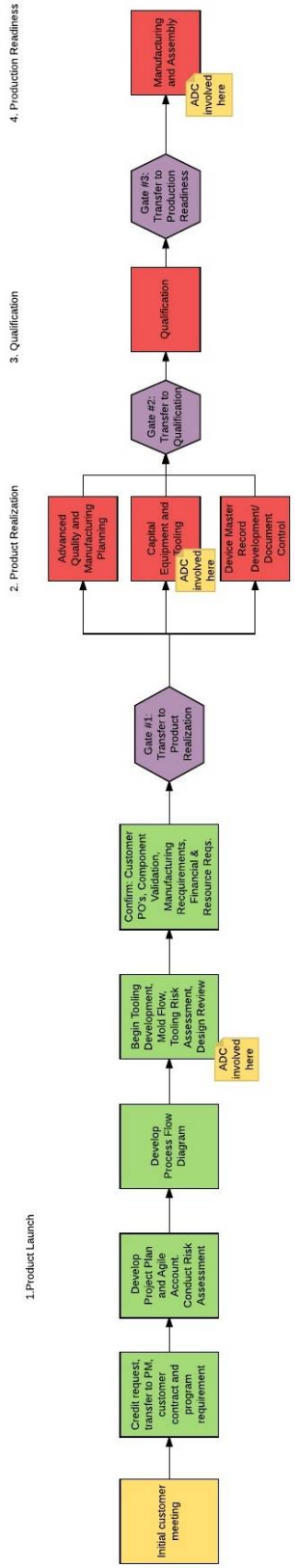

Figure 3: Mack Molding's Phase Gate Review Process Flow

The four phases illustrated within the process flow diagram are described in detail in Figure 4.

Phase	About
Product launch	This is the initiation of product within Mack Molding. This begins with the initial customer meeting and credit request. The program is then transferred to the program manager where the customer contract and program requirement. From there, aspects of the project are developed such as the project plan, the process flow of the specific project and tooling, design and risk assessment development. At the end of this phase is the first gate where the transfer to product realization occurs. Every step prior to this gate must be completed before the project can move to the next phase.
Product realization	In this phase, the different stages involved do not follow a specific order and do not need to be marked as completed prior to passing through the second gate. Through this phase, quality and manufacturing planning take place, capital equipment and tooling is finalized and purchased and development and doc control is formed, among other tasks. The gate at the end of this phase is transfer to qualification.
Qualification	Throughout this stage, validation and or qualification PO is received, tooling inspection, outside part qualification and machining qualification takes place. Furthermore, installation, operational and performance qualifications are completed. From a technical review and tooling development perspective, the designs are controlled and confirmed and scope of the project, timeline, financial tracking and resource requirements are confirmed. The third gate is transfer to production readiness.
Product readiness	This is the final stage of the Phase Gate Tracker and is centered on manufacturing and assembly. Within this stage, any required changes are made and vital components of production are verified such as material, production rate and capacity limitations are verified.

Figure 4: Phase Description Table

3.1.3 COMMUNICATION FLOW

In order to identify areas to improve within Mack Molding's product launch process; an outline of the various lines of communication within the process were established to fully understand how information is shared across departments as shown in Figure 5.

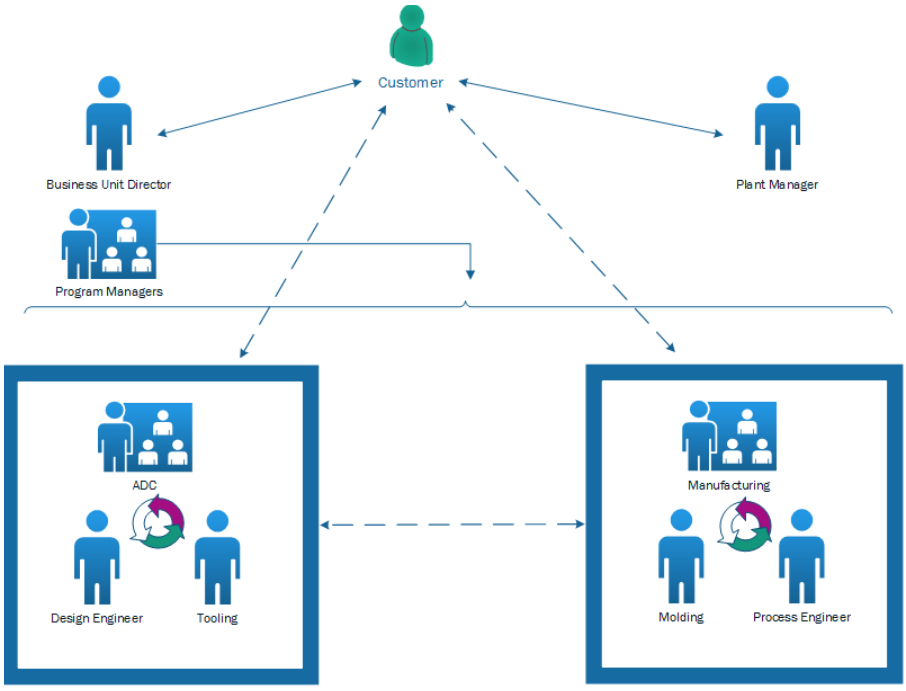

Figure 5: Communication Flow Diagram

The Business Unit Directors, Plant Manager, and Program Manager (PM) have an initial meeting with the customer to establish the project outlines. The program manager advises and controls the whole process of creating and completing a project for a customer, while reporting to the Plant Manager and Business Unit Directors. They manage the Application and Development Center (ADC) and Manufacturing departments who are responsible for different portions of the product creation. The ADC is responsible for designing the tool and product that the customer requires, then the Manufacturing department develops the manufacture processes to construct the product. The PM, ADC, and Manufacturing are able to have open communication flows throughout the project. More specifically, the ADC is made up of a tooling and design engineer who has one meeting with the customer to understand their needs, creates tool, and communicates to manufacturing what is needed. The Manufacturing department, made up of Molding and Process Engineers, are able to take the orders and physically create the product on the plant floor.

3.2 Development of New Phase Gate Tracker

3.2.1 DETERMINE NEEDS OF THE USER

There are various departments involved in the stages laid out in the process flow diagram and the Phase Gate Tracker. In order to make an effective updated tracker, the needs of all the users need to be taken into account. Getting feedback from each individual department was an important step in understanding what aspects of the Phase Gate Tracker they liked and aspects they wished to improve.

In order to gain a complete understanding of the departments and their role within the current process, interviews were conducted with key department heads. A set of base questions were presented, which aimed to grasp the current use of the tracker and the ways in which it could be improved in relation to each departments feedback. Based on the standard questions, additional questions were asked on a case-by-case basis, helping to dig deeper to uncover the root of the problem. If the needs of only some users are met, the new tracker will not be utilized by its full-intended potential. The key takeaways from each department were carefully analyzed in order to ensure the new tracker is meeting all the needs of the users. Following the interviews and focus groups, a root cause analysis diagram was developed and is depicted in Figure 6.

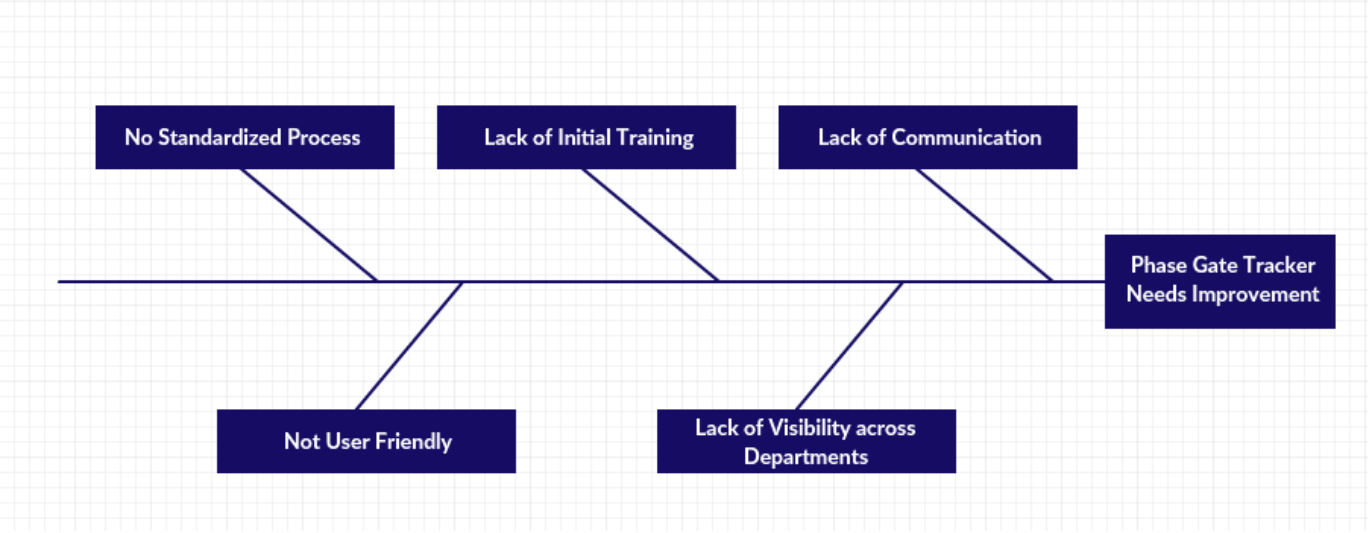

Figure 6: Root Cause Analysis

The feedback gathered from our various interviews was organized as shown in Figure 7 to display the different results from each department.

Department	Feedback
Program Managers	• Need effective communication tool • Standardized checklist • Tracker to share information across departments • Ability to generate dashboards • Increase incentive across departments to share information • Increase communication • Increase transparency of the status of each task • Increase communication of progress of each task • Improve adaptability of tracker • Establish specific individuals to monitor phase progress • Increase user-friendliness of tool
ADC	• Increase communication across departments • Ability to stay on track • Need formal structure and record process • Increase ability to identify risks • Need for phase gate training • Need uniform process for PMs and managers to view mold flow • Need a process that is hands on and does not treat everything as a crisis • Increase visibility into the customer's needs • Broadcast meeting times
Process Engineers	• Need to receive information earlier to avoid inaccurate tooling measurements • Need better communication between ADC and customers • Need better training for those on the floor • Need meeting minutes and schedule of what needs to be done • Need visibility to a product cycle Increase social communication – AIM or Slack
Manufacturing	• Increase involvement in design phase • Increase communication to avoid problems at this phase • Needs all information available in one place • Need dashboard and kick off meetings • Improve manufacturing floor layout
Quality Department	• Need product launch process • Increase visibility into customer needs • Need vital information earlier • Need visibility into the product cycle • Need for dashboard

Figure 7: Interview Feedback Table

3.2.2 IDENTIFY AREAS FOR IMPROVEMENT

Based on the employee interviews, analysis of the current tracker and process flow analysis, a focus was placed on improving the opportunities in training, creating a standardized process, user friendliness, visibility, and communication. Through interviews, pros and cons of the current tracker were gathered so the changes made would meet the needs of the users. Currently, the process lacked user friendliness. One reason for this is because it did not have any visuals for departments to track their progress. To address this, multiple project management trackers were implemented such as milestone markers and progress percentage trackers to allow the departments to have a better understanding of how they are doing within a specific project.

A large opportunity to create a new standardized process arose because the current one was too rigid. Not only does each product come with its own customer needs but also has different levels of complexity. Employees were asked about the experience of balancing the customer's needs and their department's needs, they responded, "There is no visibility of what is on deck because I answer to 17 bosses. There is a great need for a uniform process all Project Managers must follow" (Mack Molding Employee 1, personal communication, September 29, 2016). Therefore, the process designed needed to be flexible but also needed to fulfill the company's requirements. These changes create a more standardized process throughout the company.

In addition, the current process did not allow departments to see where a product was in its product cycle. To improve this, a focus was placed on departments having access to a product from beginning to end. There were also steps taken to ensure teams are told about meetings and vital information well in advance to decrease errors in production. In an interview conducted, this lack of communication was evident. "Just this morning, I was talking to one of the Project Managers and she told me the mold flow order I was placing was already made two years ago. I wasn't aware of this because there was no record of it already being placed. We need a formal record process" (Mack Molding Employee 2, personal communication, September 29, 2016). This is just one excerpt from the interviews conducted that highlight the need for making information available much earlier in the product cycle.

During the original implementation of the phase gate review process, there was no training on how to use the tool and why it was important. This led to the tool being underutilized and in some cases

departments didn't even know it existed. With the new process the team addressed how the new tool will be implemented across all departments.

3.2.3 CREATE NEW PHASE GATE TRACKER

Project initiatives to improve the overall phase gate process were achieved through a series of modifications of Mack's current Phase Gate Review Tracker. The original tool was used as a backbone for the modification made to improve the issues we uncovered throughout our interviews and visits to the site. The main problem with the tool consisted of the major underutilization of the tool directly correlating with the lack of usability of the actual tool and the lack of incentive to utilize the tool. Therefore, changes were created to the tool in order to improve the user experience, increase the incentive to utilize this tool among all departments, and improve communication across all teams in each project. To achieve our goals, the following changes were made to the Phase Gate Tracker as shown in Figures 8, 9 10 and 11.

Improved Usability	
Improved Design	● Improved layout of each page developing an easy to understand design for each page. ● Created clear titles for each tab allowing for full understanding what information can be accessed on each tab with a short glance. ● Adjusted formatting of each page allowing for improved visual pleasing appearance and increasing understanding. ● Separated data entry pages from data results pages to eliminate confusion and establishing distinction between areas. ● Created straightforward charts and tables with titles to provide easy to understand visuals.
Reduced Data Entry Error	● Granted users restricted access to the document. ● Locked certain areas of the document to avoid any confusion and only granting document owners the ability to alter these restricted areas.
Developed Drop Down Menu's	● Set each cell as drop-down to decrease process time to update tasks and their status.
Generated Filtering Capabilities	● Provided users the ability to filter tasks in a manner they feel is most beneficial for completing their work.
Replaced 'Gates' with 'Milestones'	● Gathered research on phase gate review processes used in contract manufacturing settings in which we concluded to adapt our Phase Gate Tracker to increase its flexibility and adaptability to different projects.

	• Implemented milestones to eliminate unrealistic gates that are unable to be used when tasks are being accomplished simultaneously.
Developed Training Material	• Created a user guide to leave with Mack to eliminate any confusion following our departure from the site. This user guide and presentation has the ability to be utilized for new hire training. (Appendix A) • Provided users with a training presentation followed by a live demonstration allowing for a question and answer period. (Appendix B) • Provided two direct links to the user guide directly within the document itself.

Figure 8: Improve Usability

Increase Utilization	
Proposed for Initial Team Meeting:	• Proposed that an initial team meeting should be established in order to encourage involvement of Phase Gate Tool from the initial start of each project. • The initial team meeting will review essential deadlines, task assignments, and customer information providing incentive for team members to attend.
Increased Accountability Among Departments:	• Modified the cells associated with a task to automatically populate with a team member dependent on the department. • Created a designated area for electronic signatures to provide accountability and acknowledgement among team members regarding their specific tasks. • Established incentive to update status of each task to improve team communication; in addition, eliminating wasted emails, phone calls, etc. of questions relating to the status of a specific tasks. • Formatted any cells to be highlighted in 'Red' when task is updated to 'Delayed' alerting the document owner of any possible inabilities to meet essential deadlines.
Developed Automatic Email Templates:	• Developed email templates programmed to be sent as a reminder to update tasks dependent on an adjustable timer that the document owner can decide on dependent on related deadlines.

Figure 9: Increase Utilization

Improve Communication	
Improved Layout:	• Added in additional columns to establish a location for each task and allowed for the cell to directly link to the document. • Added additional column for comments providing the task owner to record personal notes or notes the user would feel is beneficial for the team to know regarding a certain task. • Created an additional 'Team' page requiring any information covered in the initial kick off meeting to be document to provide users with the ability to review deadlines, customer information, and task assignments to improve ability to manage various projects.
Assigned Ownership to Tasks:	• Formatted each task to automatically populate with a task owner eliminating any confusion regarding the status of a task or who currently has a specific document.
Created a Shared Drive Folder Organization:	• Developed the Phase Gate Tracker Template that will follow a specific folder organization allowing for clear communication on where to locate any project's associated Tracker. • Provided specific naming conventions for each folder allowing for the ability to quickly search a project or document.

Figure 10: Improve Communication

Improve Project Management Capabilities	
Developed Automatically Generated Results Pages:	• Developed automatically generated charts, tables, and progress trackers to display results and progress visually. • Organized data in a visually pleasing manner, breaking down the project by milestones, task completion, departmental progress, and team progress. • Designed the results pages to act as tools that can easily be transferred to specific reports that are needed quickly. Designed the results pages to appear in a dashboard set up to adhere to the user's requests.

Figure 11: Improve Project Management Capabilities

3.3 Implementation of Revised Phase Gate Tracker

3.3.1 USER TRAINING

In order to effectively implement the new design of our Phase Gate Tracker, it was necessary to provide training materials for users and an informative presentation to review the overall process and our recommendations for success. A group training session was provided with all program managers,

individuals responsible for the tracker, and anyone who was interested in learning more about the Phase Gate Tracker and its purpose. The training group consisted of a presentation reviewing the program management tool, how it can be successfully utilized, and the improvements we made to the original tool. Following the presentation, the group was provided with an interactive demo of the tool that allowed for any question and answer on how to specifically navigate and use the tool their advantage. Positive feedback was received and minor adjustments were made to our tool following our training session to improve our new Phase Gate Tracker. Lastly, a user guide was developed and distributed in order to answer any questions about how to use the tool and potentially eliminate any confusion. See Appendix A and Appendix B for Phase Gate Tracker User Guide and Slide Deck.

4.0 RESULTS

4.1 PROCESS IMPROVEMENTS

The previous process flow revealed that the tracker has a rigid gate after each phase resulting in lack of flexibility within the tracker. This meant that all the steps in the phase needed to be completed before the project could move through the gate and onto the next phase. While the concept of the gate was to hold accountability, many of the times different steps in multiple phases can work in tandem, instead of sequentially. The new process flow as shown in Figure 12 now shows how the updated tracker allows for more flexibility that Mack needs. Aside from the first phase and gate, which was modified to a milestone, the last three phases work simultaneously. In addition to the flow re-work, updates were made to create a more transparent process. Sections for links to locations of crucial project information were created and notes can now be kept in the tracker, keeping all valuable information to the project in one easily accessible location.

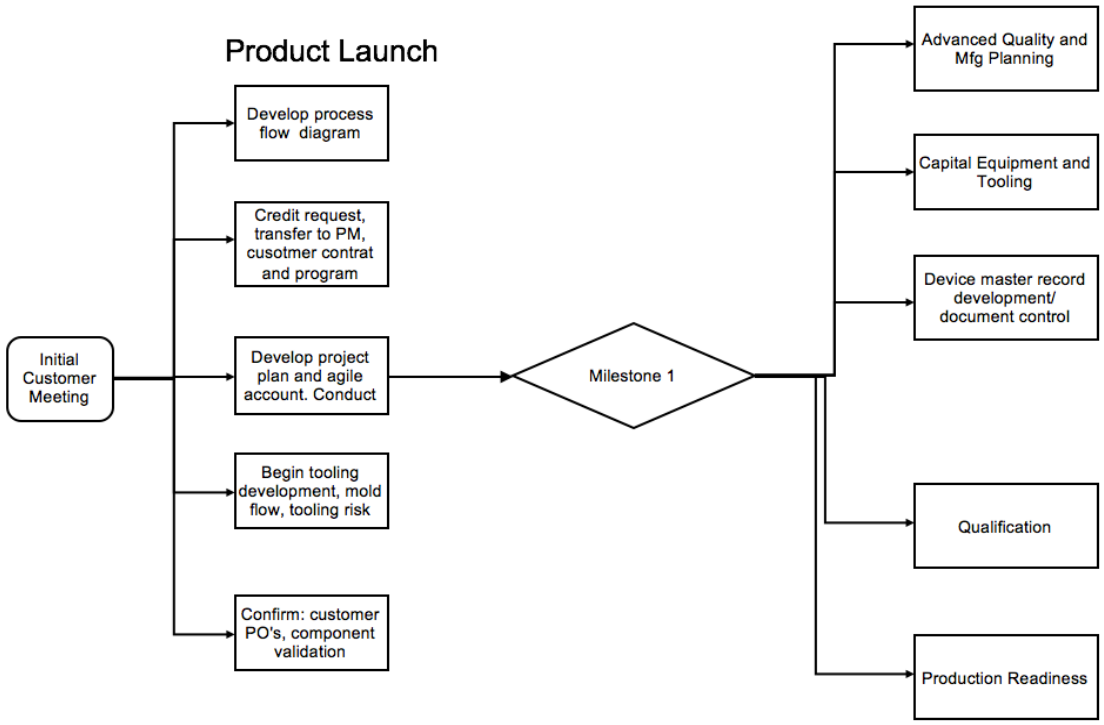

Figure 12: Revised Process Flow Diagram

Phase Gate

The original Phase Gate Tracker was underutilized and most employees were unaware of the tool. Employee's shared their insight on ways to revamp the old Phase Gate Tracker and create a better user experience. Along with user experience, functionality and accuracy were a critical aspect of designing the new Phase Gate Tracker. The Phase Gate Tracker was a combination of a Phase Gate and Milestone Tracker. This best fit the versatility and range of products within the manufacturing processes of Mack Molding. It allows for documentation of tasks and assignments needed to be complete throughout a launch of a project. The tool is simplistic and easy for users to enter their necessary information, allowing for an accurate report for management. The following benefits were created with the new tracker:

- Accurate Project Tracking
- Updated Project Status's
- Readable Dashboard
- Better Employee Adaption
- Transparency and Accountability

4.2 AXIOMATIC DESIGN

The Axiomatic Design Decomposition was used to accurately define the problems and objectives of this project through the three functional requirements (FR's) displayed in Figure 13. The FR's used to conduct our project successfully, included processing work task, measuring accountability across departments, and communicating effectively. We satisfied these FR's through a series of analysis, research, and process improvements within their current system.

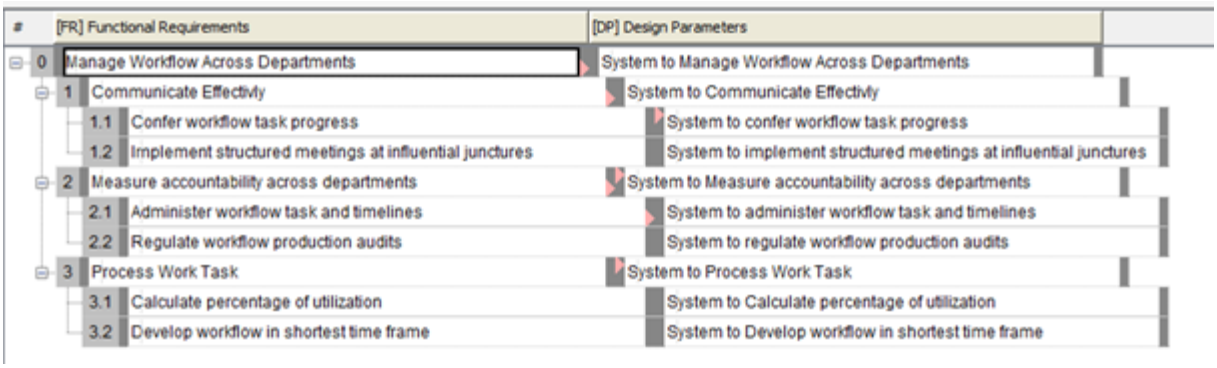

Figure 13: Axiomatic Design

Following the decomposition, we developed the axiomatic design matrix as shown in Figure 14.

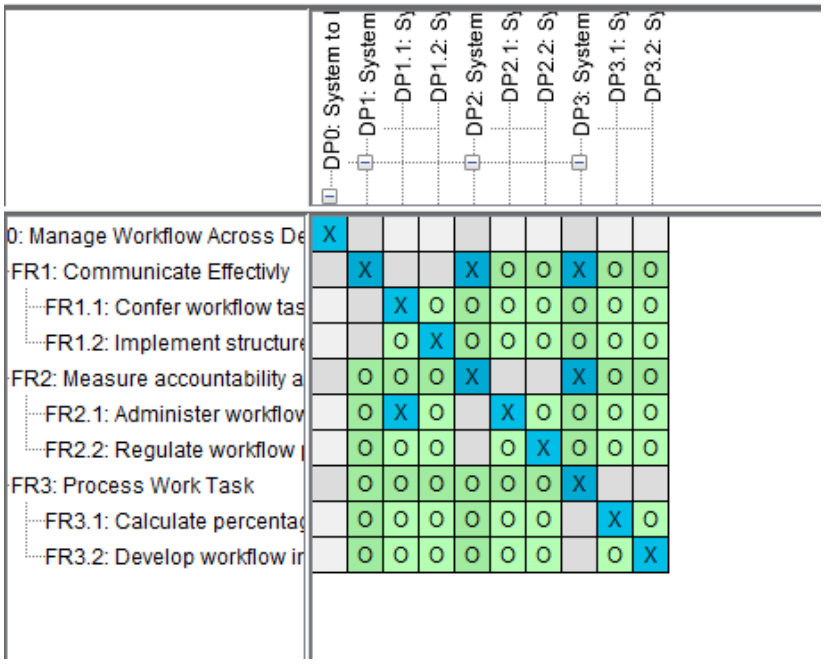

Figure 14: Axiomatic Design Matrix

FR0: Analyzing the information received through interviews, spreadsheets and emails the Axiomatic Design is structured upon three functional requirements and three design parameters to deal with them. Accomplishing these goals resulted in the internal accomplishment of Mack Moldings primary objective of managing workflow across departments.

FR1: Communicating effectively was managed through our Communication Flow Analysis. The template was organized to include various ways of transferring information across Mack Molding's information database. With the introduction of new hire template guide, work communication and training given to employees was improved.

FR2: Measuring accountability across departments was accomplished through the new Phase Gate Tracker. Introducing a system to give individuals specific task allows for people across departments to see who is responsible for different aspect of a project and the amount of development attained within the project timeline. This level of accountability was measured with the timeline to show progress.

FR3: Processing work task was achieved through the process flow analysis. This system allows for the team to track the development of the product and the utilization of the template being put in use. A numerical value is given to the level of work done so that it can be reviewed and improved upon (Suh, 1990).

4.3 OPERATION ANALYSIS

4.3.1 AHP

The Analytical Hierarchy Process (AHP) is an analytical decision-making process using mathematics and psychology. It breaks down a goal through creating criteria for each alternative. Two important metrics are created through a pairwise comparison of criteria vs. criteria and then each specified criterion from the previous calculation are compared across all alternatives. The backbones of these comparisons are the user's preferences on importance of criteria's and the numerically ranked quality of each criterion. Through these calculations a priority for each criterion is created, which is then multiplied against each alternatives criterion ranking, and summed to an overall rank. The table below displays the priority for each criterion in the first row, and the other rows display the rank of each alternative for all criteria. Figure 15 depicts data developed as it relates to Mack and the tracker and then used to create the rank of three alternatives, displayed in Figures 16 and 17.

	Reliability	Dashboards	Structure	Versitilty
Priority	0.38	0.18	0.22	0.21
Phase Gate	0.40	0.43	0.55	0.20
Milestone	0.40	0.43	0.27	0.41
Word to mouth	0.20	0.14	0.18	0.14

Figure 165: Weights and Priority Table

Overall Priorities	
Phase Gate	0.40
Milestone	0.38
Word to mouth	0.17

Figure 15: Alternative Ranks

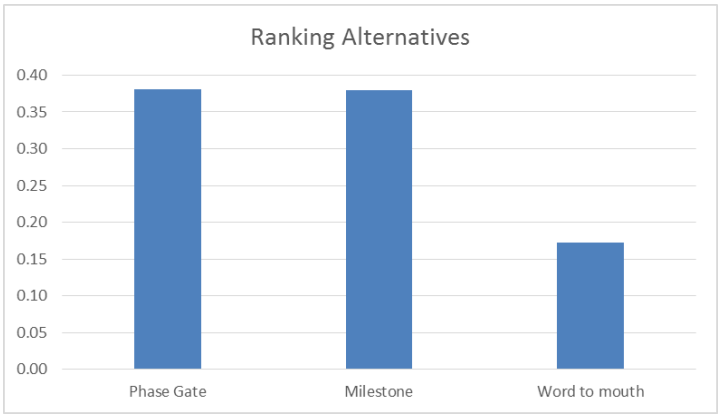

Figure 177: AHP Alternative Bar Graph

Through these calculations, we are able to convert qualitative data into quantitative data comparisons. We are able to bring all three alternatives to one overall rank and be able to identify the best option. The best alternatives from the calculations are both the phase gate and milestone options. This calculation aided in the decision making of what option to choose and after further research the decision was made to use a hybrid tracker, which included both the milestone and phase gate characteristics we desired.

4.3.2 Little's Law

Little's Law relates inventory, throughput, and lead-time. Throughput is the average rate that items flow through the process; while lead-time is the period it takes a unit of production to course through the entire process (Jacobs & Chase, 2010).

Inventory=Throughput rate * Lead Time

$L = \lambda * W$

(Source: Jacobs & Chase, 2010)

Little's law can be used to measure total inventory or the work in progress (WIP), depending on the system that is being reviewed. WIP is the number of goods going through production. For a contract manufacturer, such as Mack Molding, the unit of measure could be chairs, car parts, ice-cream machines, or other manufactured products. In the Little's Law equation, throughput would be the departure rate of the goods. An example would be five chairs per hour are being produced. The lead-time is the time a product spends in the chosen system. For example, if it takes 3 weeks for an ice-cream machine to go through the designated system then the lead-time of that item was 3 weeks. Based on the system in place lead time might be referring to minutes, hours, days, weeks, months or even years. The lead-time can refer to both the time after a customer orders the product and the time when production starts for the manufactured goods. Using these three inputs Little's laws can be used to analyze and improve worker behavior, such as increasing throughput to reduce WIP or increase process speed to limit the WIP. It is a flexible principle of industrial engineering which starts with choosing what the system is, and which manufactured products travel through the proposed system (Jacobs & Chase, 2010).

If Mack Molding's average project completion rate is 6 projects every month, and each project takes an average of 7 months to complete.

Little's Law is thus shown as:

$L = \lambda * W$

42 Projects = 6 projects per month X 7 months per project

If Mack began using the new phase gate tracker and process improvement techniques, ideally, the completion rate would improve. If the average completion rate improved to 8 projects per month rather than the original 6 projects per month, lead-time would decrease by 5.25 months. The Little's Law improvement is presented below:

Improved Lead Time = (42 projects / 8 projects per month) = 5.25 months

The recommendation for Mack through the analysis of Little's Law was to implement the Phase Gate Tracker throughout the company.

4.3.3 SPC

Statistical Process Control (SPC) is an approach for observing a process to identify variation and signal for corrective actions. The use of X bar and R bar charts are used to analyze the data going through the process. X-bar and R charts have several applications that can be used to assess the system's stability when improving or editing the system. The X-bar chart shows the average production changing over time, while the R chart shows the range of the subgroups changing over time (variability) as demonstrated in Figure 18. It is also used to observe the effects of process improvement. To look for instability in the process we check if the data is outside the systems control limits or is moving in a trend (Jacobs & Chase, 2010).

All control charts have

1. Upper control limit (UCL)
2. Lower control limit (LCL)
3. Central line (CL)

Trends in data

- Point outside control limits
- Sudden shift in process average
- Cycles
- Trends
- Enfolding the center line
- Enfolding the control limits
- Instability

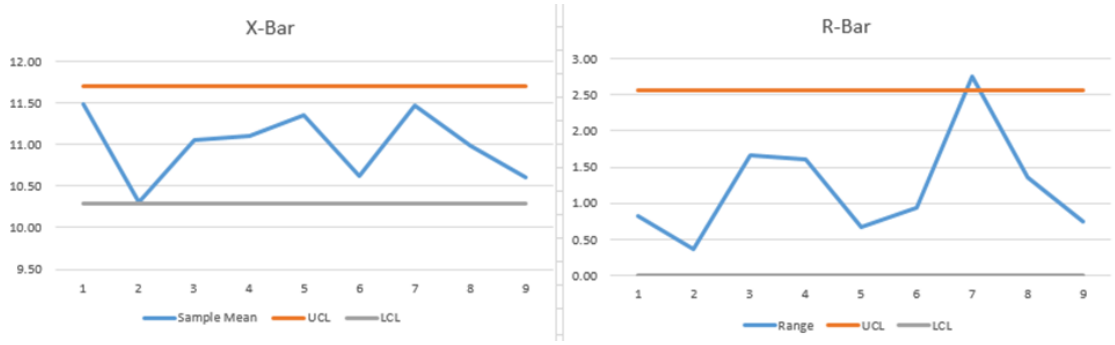

Figure 18: X-Bar and R-Bar Chart

The results of using SPC are finding dissimilar results between shifts, laborers, tools, machines, and other manufacturing factors. The systems collect and analyze the data throughout the process to know if change occurred and to identify sources of process variability, which helps with standardization. As a contract manufacturer, Mack molding has to produce a variety of parts and tools that, during

production, have specifications in size to which they must adhere. If there's a discrepancy in the data then using SPC will help find it (Jacobs & Chase, 2010).

4.3.4 Financial Analysis

After calculating the savings of the tracker, financial analysis was done by assuming some of the following data. The first assumption used was the salary of each user of the launch tracker. The yearly salaries are as seen in the following table. These were obtained by researching the national average for each position through Glassdoor. Yearly salaries were applied towards active number of employees at the company in Figure 19.

	PM (Project manager	SQE (Senior Quality engineer)	QE (Senior Quality engineer)	ME (Mechanical engineer)	ADC (application and development center)
Yearly salary (National average)	$89,286	$78,184	$73,000	$70,000	$73,665

Figure 19: Cost vs. Benefit Analysis

The second assumption made is the number of days an employee works per year. On average, an employee works 50 out of 52 weeks of year, due to vacation, holidays, Etc. Within these 50 weeks, only 5 out of the 7 days are true workdays; an employee works roughly an 8-hour workday. This equates to a yearly average of 250 days of work per employee. The 250 days are then divided by total month to obtain a rough estimate of days per month, which equates to 20.38 days per month. The tool saves roughly 15 minutes of non-value added time, which equates to about 306 minutes saved per month.

With these two assumptions, we are able to calculate the monthly savings produced per employee. The total savings comes to about $2,500 of savings per month. The net present value of saved employee time over a two-year period is about $49,000.

Another financial benefit is the reduction of tool reworks. The two assumptions made is that a rework cost $2,000 and the number of reworks were reduced by one each month. This calculates out to $2,000 of savings each month. The net present value of reduced rework over a two-year period is about $40,000.

Another financial benefit is the reduction of time to market. This means with less time wasted on repeat tasks there is faster time to market; which is beneficial because the product can be shipped out

sooner. To calculate this value the Average number of days reduced to deliver product per month is multiplied by number of projects reduced per month. Then this calculated number is multiplied by savings per day. This equates to a two-year period savings of $29,359.14.

A financial cost considered is training for the new tracker. Training takes away from everyday activities and costs the company an employee's salary. The assumptions made in this calculation is that training takes away 2 hours of an employee's monthly work schedule and training occurs every month. By calculating the hourly employee salary per position and multiplying it by the total hours of training per employee yields the monthly training cost. The cost of training per month is about $1,000. These calculations can be seen in Figure 20.

Figure 20: Cost vs. Benefit Analysis

6.0 CONCLUSION

The objective of the project was to improve the Phase Gate Tracker currently being used at Mack Molding. The Phase Gate Tracker is an Excel document used to track the progress of individual projects. Each department holds responsibility over updating an assignment's status and location. This document accumulates the tracking data, which reports the development status of the overall project. Easier communication, supplementary transparency and a reduction of non-value added time are all key elements of the system.

The tracker is needed to assign tasks, review project progress, answer imperative questions, and create a positive user experience. These elements are critical to completing a project thoroughly and on time. The current phase gate used at Mack was underutilized due to a lack of employee knowledge about

the tool and poor user experience with the tracker. These issues were found through employee think sessions that generated common issues to address in the tracker.

The modification that the team made to the Mack Molding system was the implementation of a new Phase Gate Tracker design. The changes included updating the phase gate design into milestones with new information requirement features. For example, the department ownership for status updates was added to clarify responsibilities and forecasting of job completion. Another example is the creation of a dashboard for upper management to have simple way of checking the progress of certain projects. These modifications achieved the following goals:

- Utilization of the tool within each department
- Increasing accessibility of project objectives
- Reduction of project timelines
- Improvement of team efficiency
- Increased visibility of all projects

Overall the updated tool has had a positive impact on the company's project tracking capabilities. While the new tracker has not been fully utilized by the entire company, the team foresees that the tracker will be implemented as employees begin utilize the training modules that the team made.

6.1 Recommendations

Recommendations	Explanation
Enhance Employee Communication	Encourage employees to use a messaging system (slack, AIM) to save time trying to locate someone physically within the plant
Instill More Team Meetings	Encourage departments to stay involved in the project whether their phase in the project is completed or upcoming
Purchase Interactive Dashboard Software	Provide employees with a desired dashboard, which acts as a quick visual to view a projects progress
Attend Kick Off Meetings	Increase employee moral by inviting all departments to this meeting. It is important to start projects off on a positive and uniform note
Review Phase Gate Tracker	Generate awareness into assigned tasks by reviewing and updating tasks within 24 hours of any change
Utilize Phase Gate Tracker for Increased Efficiency	Produce all information available in one place and increase visibility into projects
Enhance User Guide Training	Build off of the user guide provided and educate employees on how to properly navigate this tool and the importance of it being utilized
Create Uniform Process Amongst Project Managers	Develop a process which all project managers will adopt in order to create a uniform plan across departments

Figure 21: Recommendations Table

6.2 Interdisciplinary Reflection

Since our team is composed of three management engineers and two industrial engineers we were able to each bring diverse knowledge through excel, financial modeling, and process improvements. From these different backgrounds, we were able to identify a recurring problem at Mack Molding. Through process and communication flow analyses; we found a need for Mack to improve their current project management process. Following the definition of the problem we researched feasible solutions and suggested a new project tracker would be the most effective solution for Mack. We were able to develop this tracker using our experience in classes such as Achieving Effective Operations, Stochastic Models and Materials Management in Supply Chain. The School of Business focuses heavily on how to successfully implement a change within a company and how to understand a business' and employee's needs. After developing our tool, we created an analytic hierarchy process and financial models to back up our project with data. Using these techniques, the team analyzed the complex decisions of changing tracking system, leading to the decision that with essentially no investment the company would obtain a higher level of efficiency and profit.

Some classes that were helpful in this modeling was: OIE 2850 engineering economics, OIE 3420 quality planning, design, and control, BUS 2080 Data Analysis for Decision making, BUS 3020 achieving Effective operations, and OIE 3510 Stochastic Models.

Throughout our project, the team made multiple versions of the tracker. We stayed in constant contact with a project manager at Mack, who would review the tracker and send feedback to the team. From the start, we built a tool she felt would be utilized by the company, but had a few suggestions to make it more personalized to Mack. In order to do this, we made an effort to better understand their culture. One change we made to the tracker was changing a few words to fit with the language used within the company. The team also knew the tool would only be utilized if the employees felt it would help them to do their jobs better. The interviews conducted with employees in different levels and departments allowed us to get a variety of insights and recommendations to apply to the tool.

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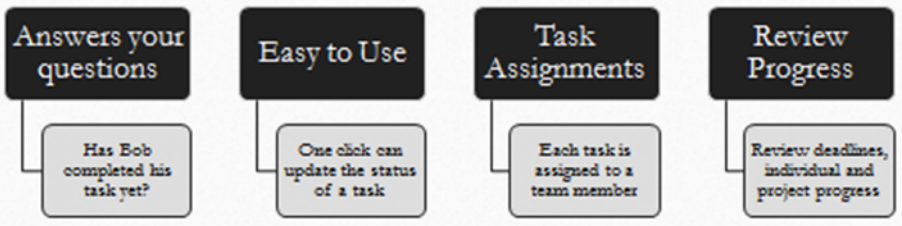
8.0 APPENDIX

Appendix A- Tracker User Guide

Phase Gate Tracker- What is it?

- Excel document to be used to track the progress of a project
- Each department is responsible for updating their assigned task's status & locations
- Provides access to general project information and project progress to entire team
- Allows for easier communication across the team
- Eliminates wasted time of tracking down documents

Phase Gate Tracker-Why should you use it?



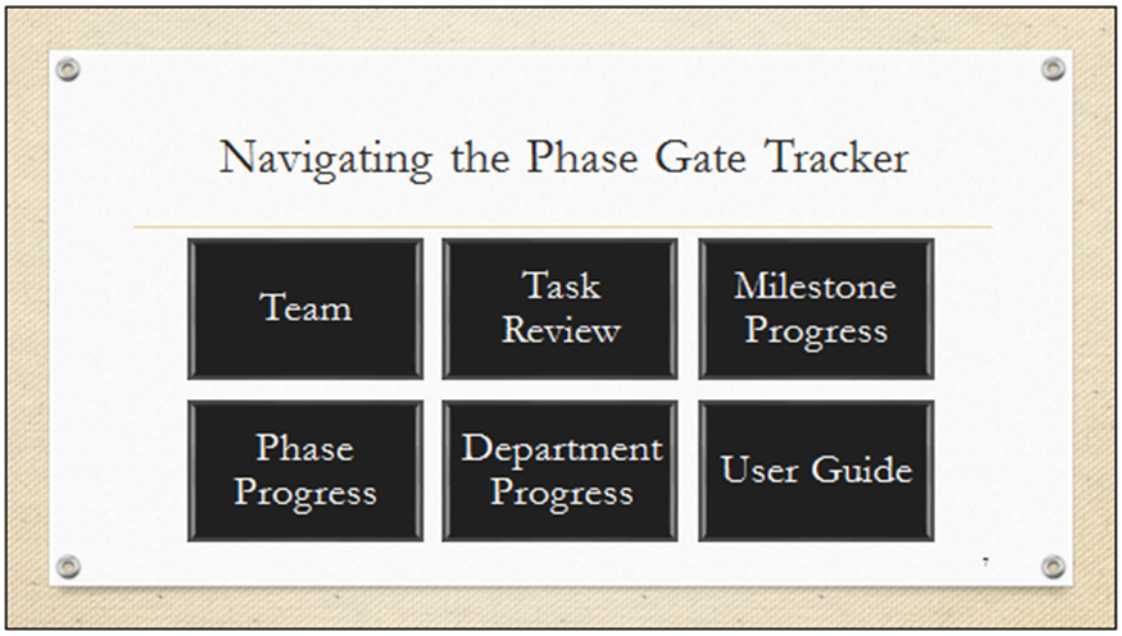
Modifications

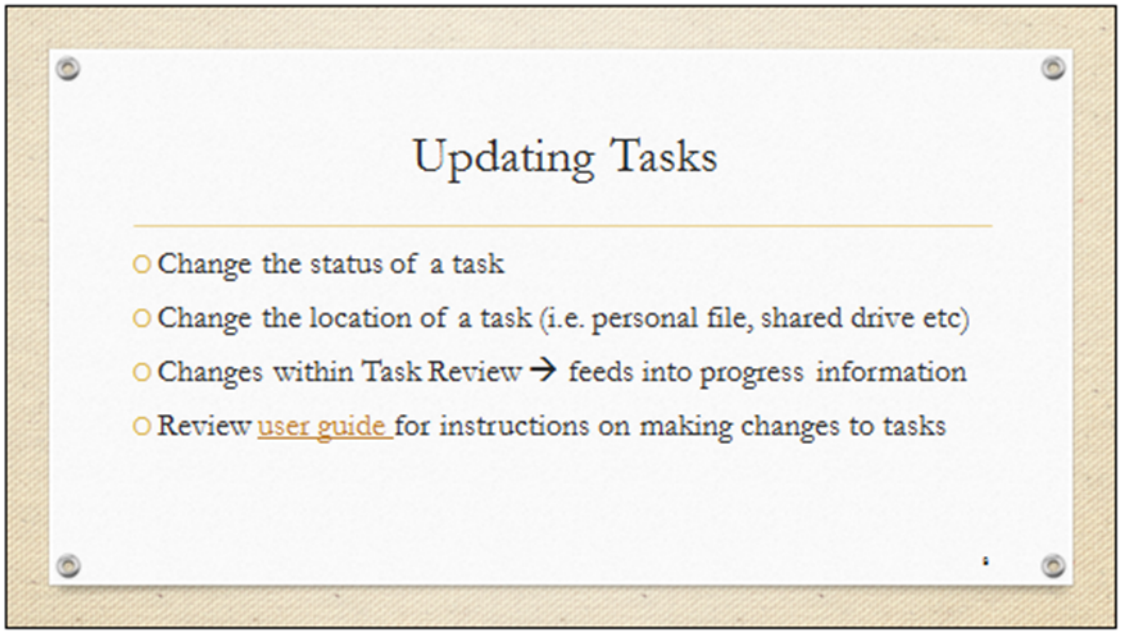
- New Design
- Gates→ Milestones
- New Requirements
- User Friendly

Your Responsibilities

- Attend Kick Off Meeting
- Review Phase Gate Tracker and assigned tasks
- Provide e-signature
- Update task's status or location as they change within 24 hours

New Project → Kick Off Meeting → Review Phase Gate Tracker


Navigating the Phase Gate Tracker
Team
Task Review
Milestone Progress
Phase Progress
Department Progress
User Guide


Updating Tasks
Change the status of a task
Change the location of a task (i.e. personal file, shared drive etc)
Changes within Task Review → feeds into progress information
Review user guide for instructions on making changes to tasks

Updating Tasks

- Change the status of a task
- Change the location of a task (i.e. personal file, shared drive etc)
- Changes within Task Review → feeds into progress information
- Review user guide for instructions on making changes to tasks

GOALS

- Utilize tool within each department for updates
- Increase ability to access information
- Develop clear objectives of each project
- Reduce timelines of each project
- Improve efficiency among teams
- Increase visibility of all projects

Appendix B- Phase Gate Tracker Guide

Phase Gate Tracker User Guide

PHASE GATE TRACKER

MACK MOLDING

Introduction

The Phase Gate Tracker includes six pages organized at the bottom of the document as six tabs. You can access any page by selecting the tab of the page. If you are unable to view all six tabs you can use the arrow keys shown to the left of the first tab to scroll through the six tabs. Learn more about what each tab includes in the table below.

Tab	Description
Team	• Access any general project or team information here • View the essential due dates associated with this project • Use the table on this page to provide E-signature • Access any additional information your PM wishes to provide

Task Review	• Review all the tasks and associated phases within this page
	• Different columns in each phase allow:
	  ○ Updating Status of a Task
	  ○ Adding Comments to a Task
	  ○ Changing the location of a Task/ Document
	• All columns are capable of filtering for various viewing purposes

Milestone Progress	• Review completion of each milestone • Review the number of tasks remaining within a milestone • Utilize the Milestone Completion chart for project management/tracking purposes

Phase Progress	• Review the progress of each phase including:
	  ○ The percentage of tasks in each status
	  ○ # of tasks in each status
	• The status of completion in each Table/ Chart are transferrable (Copy & Paste as Image)

Department Progress	• Review the progress of each department including:
	  ○ # of tasks within in each status
	  ○ Total # of tasks within each status for all departments
	• Review the completion of tasks by department in the chart:
	• Blue bar indicating % completion

User Guide	• Access any information on how to use this tracker • Jump to different headings to get answers to specific questions • Quickly access this user guide in the link provided at the top of the Task Review Tab 🗨 *For any additional questions you have regarding this document, contact your P.M.*

Navigation

Review Tasks

Open the Tracker within the shared drive
Open **Task Review** tab:
Locate task and select this cell
Use your arrow keys to review the associated columns

Change the Status of a Task

Select the cell in the 'Status' column associated with a specific task you would like to change
Use the drop down menu to select the status of the specific task

If a task is done to its entirety	Complete
If a task is open and not complete	In Progress
If a task is open and cannot be completed for any reason	Delayed

Continue this process for each task you wish to change
Save changes

Filtering Tasks

Filtering Personal Tasks

Open **Task Review** tab
Navigate to the specific phase you would like to view
Select the 'Primary Role' cell
Select the drop down arrow within that cell
Click 'Select All' in the drop down menu to quickly de-select all names
✔ Check off your name and click 'OK'
If done correctly, you should now be able to see only the tasks associated with your name
Repeat the previous instructions for each phase you would like to filter

Filtering Status of Tasks

Open **Task Review** tab
Navigate to the specific phase you would like to view
If you wish to only view the status of your own tasks: Follow the steps provided in 'Viewing Personal Tasks' and continue
Select the 'Status' cell
Select the drop down arrow within that cell
Click 'Select All' in the drop down menu to quickly de-select all options
✔ Check off 'Complete'/ 'In Progress'/ "Delayed' or a combination of any to view only the tasks associated with that status (i.e. If you wish to only view the tasks that are 'Complete', only check off 'Complete')
If done correctly, you should now be able to see only the tasks associated with that status.

Repeat the previous instructions for each phase you would like to filter

Review Task Progress

Use the following tabs to review the progress of the project:

- Milestone Progress: *provides the status of completion of each milestone*
- Phase Progress: *separates each phase providing the the number of tasks complete, in progress, and delayed*
- Department Progress: *provides the progress of each department/individual showing the % completion of each department within the chart*

Each progress tab is automatically generated using the information provided in 'Task Review' tab. If you make changes within this tab and wish to view these changes in the progress pages:

Select 'Data' in the menu bar

Select 'Refresh All' in this menu

This will refresh the information used to generate the tables/charts on the tabs that are linked

Appendix C- AHP Model

	Phase Gate	Milestone	Word to mouth
Reliability	Relatively	Relatively	none
Dashboards	Yes	Yes	No
Structure	Yes	Some	none
Versitility	some	yes	none

Pair wise comparison	More Important	Numerical rating
Reliability-Dashboards	Reliability	2
Reliability-Structure	Reliability	2
Reliability-Versitility	Reliability	3
Dashboards-Structure	Structure	3
Dashboards-Versitility	Dashboard	2
Structure-Versitility	Versitility	3

	Phase Gate	Milestone	Word to mouth
Reliability	1	1	2
Dashboards	1	1	2
Structure	1	2	3
Versitility	2	1	3

Comparision

Criteria

	Reliability	Dashboards	Structure	Versitilty
Reliability	1.00	2.00	2.00	3.00
Dashboards	0.50	1.00	0.33	2.00
Structure	0.50	3.00	1.00	0.33
Versitility	0.33	0.50	3.00	1.00
Sum	2.33	6.50	6.33	6.33

Normalized

Criteria

	Reliability	Dashboards	Structure	Versitilty
Reliability	0.43	0.31	0.32	0.47
Dashboards	0.21	0.15	0.05	0.32
Structure	0.21	0.46	0.16	0.05
Versitility	0.14	0.08	0.47	0.16

Priority		Reliability	Dashboards	Structure	Versitilty	weighted sum	consistency Measure
0.38	Reliability	0.38	0.37	0.44	0.64	1.83	4.80
0.18	Dashboards	0.19	0.18	0.07	0.43	0.87	4.75
0.22	Structure	0.19	0.55	0.22	0.07	1.04	4.67
0.21	Versitility	0.13	0.09	0.66	0.21	1.10	5.15
						CR	0.31
						RI	0.9

Reliability										
	Phase Gate	Milestone	Word to mouth					Phase Gate	Milestone	Word to mouth
Phase Gate	1	1	2				Apple	0.4	0.4	0.4
Milestone	1	1	2				Samsung	0.4	0.4	0.4
Word to mouth	0.5	0.5	1				Android	0.2	0.2	0.2
Sum	2.5	2.5	5							

	Priority			Phase Gate	Milestone	Word to mouth		weighted sum	consistency Measure
	0.4		Apple	0.4	0.4	0.4		1.2	3
	0.4		Samsung	0.4	0.4	0.4		1.2	3
	0.2		Android	0.2	0.2	0.2		0.6	3
								CR	0.00
								RI	0.58

Dashboards										
	Phase Gate	Milestone	Word to mouth					Phase Gate	Milestone	Word to mouth
Phase Gate	1.00	1.00	3.00				Phase Gate	0.43	0.43	0.43
Milestone	1.00	1.00	3.00				Milestone	0.43	0.43	0.43
Word to mouth	0.33	0.33	1.00				Word to mouth	0.14	0.14	0.14
Sum	2.33	2.33	7.00							

	Priority			Phase Gate	Milestone	Word to mouth			weighted sum	consistency Measure
	0.43		Phase Gate	0.43	0.43	0.43			1.29	3
	0.43		Milestone	0.43	0.43	0.43			1.29	3
	0.14		Word to mouth	0.14	0.14	0.14			0.43	3
									CR	0.00
									RI	0.58

Structure										
	Phase Gate	Milestone	Word to mouth					Phase Gate	Milestone	Word to mouth
Phase Gate	1.0	2.0	3.0				Phase Gate	0.55	0.55	0.55
Milestone	0.5	1.0	1.5				Milestone	0.27	0.27	0.27
Word to mouth	0.3	0.7	1.0				Word to mouth	0.18	0.18	0.18
Sum	1.8	3.7	5.5							

	Priority			Phase Gate	Milestone	Word to mouth			weighted sum	consistency Measure
	0.55		Phase Gate	0.55	0.55	0.55			1.64	3
	0.27		Milestone	0.27	0.27	0.27			0.82	3
	0.18		Word to mouth	0.18	0.18	0.18			0.55	3
									CR	0.00
									RI	0.58

Versitilty										
	Phase Gate	Milestone	Word to mouth					Phase Gate	Milestone	Word to mouth
Phase Gate	1.0	0.5	1.5				Phase Gate	0.27	0.27	0.27
Milestone	2.0	1.0	3.0				Milestone	0.55	0.55	0.55
Word to mouth	0.7	0.3	1.0				Word to mouth	0.18	0.18	0.18
Sum	3.7	1.8	5.5							

	Priority			Phase Gate	Milestone	Word to mouth			weighted sum	consistency Measure
	0.20		Phase Gate	0.20	0.20	0.20			0.61	3
	0.41		Milestone	0.41	0.41	0.41			1.23	3
	0.14		Word to mouth	0.14	0.14	0.14			0.41	3
									CR	0.00
									RI	0.58

Priority Summary								
	Reliability	Dashboards	Structure	Versitilty			Overall Priorities	
Priority	0.38	0.18	0.22	0.21				
Phase Gate	0.40	0.43	0.55	0.20			Phase Gate	0.40
Milestone	0.40	0.43	0.27	0.41			Milestone	0.38
Word to mouth	0.20	0.14	0.18	0.14			Word to mouth	0.17

Appendix D- Financial Analysis

	Rate (Inflation rate)		0.017	1.70%			
Months	Employee Time savings	Time to Market	Less Rework	Training	Total	Quarters earnings	
1	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
2	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
3	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89	$ 54,863.35	Y1Q1
4	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
5	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
6	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89	$ 54,863.35	Y1Q2
7	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
8	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
9	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89	$ 54,863.35	Y1Q3
10	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
11	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
12	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89	$ 54,863.35	Y1Q4
13	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
14	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
15	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89	$ 54,863.35	Y2Q1
16	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
17	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
18	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89	$ 54,863.35	Y2Q2
19	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
20	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
21	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89	$ 54,863.35	Y2Q3
22	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
23	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89		
24	$ 2,465.73	$ 5,625.00	$ 2,000.00	$ (946.84)	$ 9,143.89	$ 54,863.35	Y2Q4
NPV Year 1	$48,261.22	$110,096.76	$39,145.51	($18,532.31)	$178,971.18		

Employee Time savings					
Role	PM	SQE	QE	ME	ADC
Total # employed	4	2	2	2	2
salary	$ 89,286.00	$ 78,184.00	$ 73,000.00	$ 70,000.00	$ 73,665.00
Salary per hour	$ 44.6	$ 39.1	$ 36.5	$ 35.0	$ 36.8

Days of work	250
days per month	20.83
time saved per person (Hours/Month)	5.21

Less Rework	
Avg number of reworks per month	1.00
Avg Cost of reworks	$ 2,000.00

Time to market Savings	
Avg # of days reduced to deliever product per month	1.50
# of Projects reduced	15.00
Savings per day	$ 250.00

Overall benefits on top of savings
Eliminate over time
eliminate expense of one employee
Allows to shift 1 personal towards something else
Take on more jobs (productivity)

Appendix E- Statistical Process Control

Input	
Number of samples	9
Sample Size (n)	5

Output	X-Bar
UCL	11.70
Mean	11.00
LCL	10.30
R-Bar	1.21

N	5
A2	0.577
D3	0.00
D4	2.114

X-bar & R Chart

$UCL_X = X + (A_2)(R)$

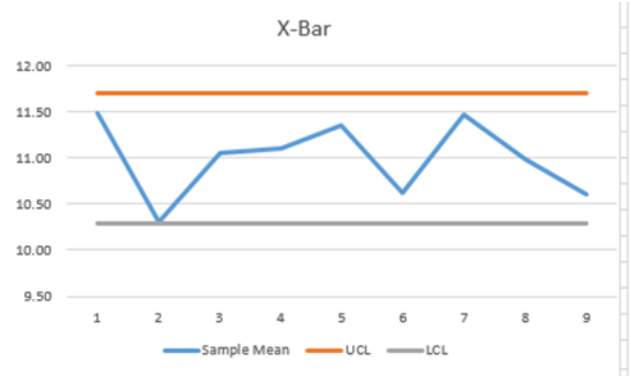
$LCL_X = X - (A_2)(R)$

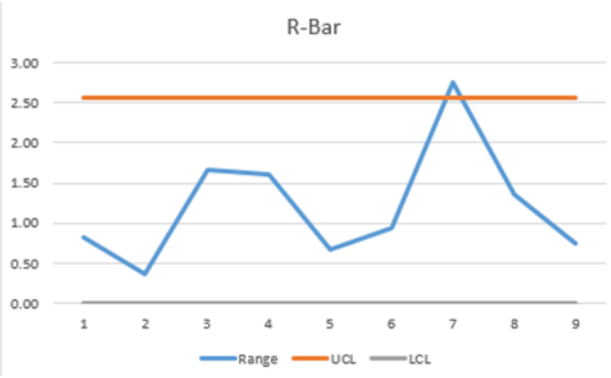
$UCL_R = (D_4)(R)$

$LCL_R = (D_3)(R)$

	Observations										
Samples	Obs 1	Obs 2	Obs 3	Obs 4	Obs 5	Sample Mean	UCL	LCL	Range	UCL	LCL
1	11.549	11.385	11.799	11.727	10.970	11.49	11.698	10.297	0.83	2.566	0.000
2	10.112	10.227	10.485	10.273	10.397	10.30	11.698	10.297	0.37	2.566	0.000
3	11.605	11.736	11.094	10.082	10.776	11.06	11.698	10.297	1.65	2.566	0.000
4	11.526	11.519	11.847	10.236	10.376	11.10	11.698	10.297	1.61	2.566	0.000
5	11.573	11.390	10.903	11.331	11.553	11.35	11.698	10.297	0.67	2.566	0.000
6	10.175	10.656	10.376	11.110	10.769	10.62	11.698	10.297	0.94	2.566	0.000
7	12.956	10.207	11.065	11.643	11.459	11.47	11.698	10.297	2.75	2.566	0.000
8	10.544	10.659	11.900	11.143	10.714	10.99	11.698	10.297	1.36	2.566	0.000
9	10.861	10.776	10.112	10.714	10.584	10.61	11.698	10.297	0.75	2.566	0.000

Tabular values for X-bar and range charts				
n	A_2	d_2	D_3	D_4
2	1.88	1.128	0	3.268
3	1.023	1.693	0	2.574
4	0.729	2.059	0	2.282
5	0.577	2.326	0	2.114
6	0.483	2.534	0	2.004
7	0.419	2.704	0.076	1.924
8	0.373	2.847	0.136	1.864
9	0.337	2.97	0.184	1.816
10	0.308	3.078	0.223	1.777
11	0.285	3.173	0.256	1.744
12	0.266	3.258	0.283	1.717
13	0.249	3.336	0.307	1.693
14	0.235	3.407	0.328	1.672
15	0.223	3.472	0.347	1.653
16	0.212	3.532	0.363	1.637
17	0.203	3.588	0.378	1.622
18	0.194	3.64	0.391	1.608
19	0.187	3.689	0.403	1.597
20	0.18	3.735	0.415	1.585
21	0.173	3.778	0.425	1.575
22	0.167	3.819	0.434	1.566
23	0.162	3.858	0.443	1.557
24	0.157	3.895	0.451	1.548





Appendix F- Little's Law

Little's Law Calculator								
		Time in:	Hours					
Total Cycle Time	=	Number of Items in Process						
		Average Completion Rate		Hours				
A) To determine the Cycle Time from Completion Rate (Demand) & Work-In-Process:								
			3.72	Hours	=	186	Units in Process	
						50	Units Per	Hours
B) To determine Completion Rate for a given Lead Time and Work-In-Process quantity:								
			3	Hours	=	159	Units in Process	
						53	Units Per	Hours
C) To determine Work-In-Process from Cycle Time and Completion Rate:								
			4	Hours	=	108	Units in Process	
						27	Units Per	Hours