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An Improved Custom Development Process Utilizing Lean Methods and Tools

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Abstract

Works have been written on the applications of lean principles and methods to product development, manufacturing, and the office. However, works written on the applications applied to research and development and custom product development processes have been exclude because of the inherent variability in the product design process. This work applied lean principles and tools to custom product development processes. A furniture company with $1.3 billion in annual sales, custom product development process was studied and lean principles, behaviors, and tools were applied using a traditional six step approach mixed with non-traditional practices as well. Within the six steps, the approach negated the differences in the products, and their quantities, which high-volume low-mix is based, and focused on capturing and creating common processes or methods used to make the variety of custom products requested, in low-volume, high-mix processes. Once the common activities were standardized, waste was identified and eliminated through kaizens just like traditional lean practices. This methodology of mixing traditional and non-traditional lean tools can be applied to any high mix or variable process such as custom industries: custom bearings or custom cabinetry and this paper provides businesses with example of how lean methods and tools can be applied to a variable process, like a custom development process.

Keywords: Product Development, Lean Product Development, Value Stream Mapping, Lean Culture

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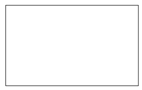
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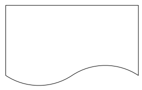
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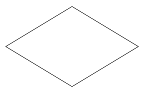
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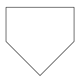
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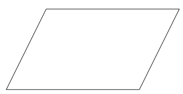
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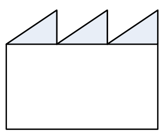
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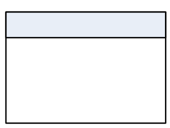
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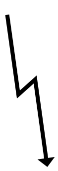
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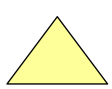
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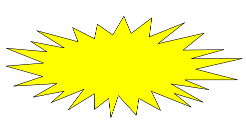

Kaizen Burst

List of Acronyms

I. Introduction

Lean principles have been applied to manufacturing and product development since the book *The Machine the Changes the World* by, James Womack, Daniel Jones, and Daniel Roos in 1991 and *Thinking Lean* by James Womack was published in 1996 a. The inherent variability in product design has prevented Lean from being applied to custom product development and research and development processes. In this work a custom product development process at a furniture company was studied and the lean methodology was applied to the process.

a. Custom Product Definition

The furniture industry creates and sells custom products daily in addition to their standard products but the custom product makes up only 8.80 percent of their 1.3 billion dollars in sales (Crosson, 2010). In the furniture business products are manufactured according to an order. Within an order both the standard product and the custom product must be manufactured simultaneously in order to ship to the customer collectively. A *standard product* is defined as a product that has undergone the new product development process. The deliverables of the new product development process (NPDP) include a completed set of component and assembly drawings, a bill of materials, manufacturing plans, validation testing, distribution plans, cost analysis, product price and cataloging, an example of the NPDP is shown in Appendix A. After these products are cataloged, they are available for customer selection. A *custom product* is defined as a product that deviates from a designed product. A custom product in the furniture industry, for example, can be a desk-top unit that is to be "stretched and pulled," which is to lengthen and or widen the desk-top unit to make it larger than what is currently offered in a published or online catalog. Another example is of a customer that wishes to use his or her own material, referred to as Customer's Own Material (COM). A COM may be fabric, wood-veneer, or laminate instead of the standard choices listed in the catalog to make the product. A third example, a customer requests an entirely new design, but uses a standard catalog product as the base or starting point in which the new design starts. The custom product designs options are infinite; therefore, drives the process to be variable and unpredictable. This variation has deterred lean practitioners from applying the methodology to the custom development process.

Custom product development processes are used in other industries. In the automotive industry, for example, a custom product within an Original Equipment Manufacturing (OEM) is developed based on a designed, priced, and cataloged product as well. A police car and a taxi are two examples of these custom products from an OEM. One specific example is the Chevrolet Impala, which has been the base model of many police cars. The OEM has fixed the chassis, frame and engine while customizing other aspects of the vehicle for a particular police department. The vehicle has been customized with special handles, colors, seats, consoles, and locks for a particular police department.

In the bearing industry a custom bearing may be a bearing that fits the packaging envelope listed in a catalog, but the load, torque, or environmental conditions required by a customer will alter the bearing therefore making it become a custom bearing, such as bearings for turbines used in windmills for wind energy. Another instance of a custom bearing occurs when the inside load, torque, and environment conditions are the same as a standard bearing, but the exterior mounting surface needs to be altered, such as bearings used in military applications that require special housings.

In all three industries (the furniture, the automotive, and the bearings industries), the definition of what a custom product are relatively the same, a product that shares many characteristics with a catalogued product in which deviations are requested to meet the special needs of a customer. The deviated product requested in these applications are referred to as *custom* product but they should not be confused with custom product designed and produced product from “job shops.” Custom products created in or from “job shops” are out of scope of this work.

b. Custom Product Development Process

To create standard product that will satisfy the mass market, a process (NPDP) is followed. The process involves identifying or developing new manufacturing processes specifically to optimize the manufacturing process to lower the cost for that specific product or product family. Strict process rules within the NPDP utilize rigorous check points, reviews, and other measures in order to ensure that the standard product is not only a quality product, but it also meets customer design requirements as well as being cost-effective. In the custom product development process it follows its own set of processes rules which differ from the NPDP. These rules include that custom products are designed on the premise that existing equipment and manufacturing processes must be used and no cost can be incurred for purchasing new equipment to manufacture the custom product. The custom product is designed specifically upon the request of a single customer although; the single customer request could consist of one or more products and or multiples of the same products.

c. Testing Protocol

The Business and Institutional Furniture Manufacturer's Association (BIFMA) is the regulatory standards for the furniture business. Furniture products must comply with BIFMA, but custom products do not therefore do not have to be tested. The warranty on custom product is also different from standard product. The warranty for a standard wood desk-top, for example, is five years, but for a custom wood desk-top it is only one year because the there is no required testing on the custom product. BIFMA testing would drive cost higher and it is not a desired requirement of the custom product customer.

II. Literature Review

The basic principles of lean were utilized as those discussed by Liker (2004), Womack (1991 & 1996), and Rother & Shook (1998). These principles all address eliminating waste from the process. Initially there were seven wastes, the first seven, that were published by Womack (1996) and Rother & Shook (1998). Liker (2004) introduced an eighth waste resulting from the affects of people. Currently there are eight wastes. They are as follows.

1. Overproduction – Is the generating or producing more than internal or external customer needs
2. Waiting – Is idle time created when material or information, people or equipment is not ready
3. Transportation – Movement of work that does not add value
4. Motion – Movement of people, paper or electronic exchanges that does not add value
5. Over-processing – Is the putting more time or effort into work than is necessary to meet the customer's needs
6. Inventory – Is there is more information or product on hand than is necessary to meet the customer's need
7. Defects – the work or product contains an error, mistake or lacks something that requires rework (Womack, 1996, Rother & Shook, 1998)
8. Behavior – People's actions that cause frustration and reduce participation, cooperation and or commitment (Liker, 2004)

Liker utilized his 14 principles called out in *The Toyota Way* to eliminate wastes. Liker's 14 principles are the following:

1. Base your management decisions on a long term philosophy,
2. Create continuous flow to bring problems to the surface,
3. Use "pull" systems to avoid overproduction,
4. Level out the workload,
5. Build a culture to stop and fix problems,
6. Standardized task are the foundation,
7. Use visual control so no problems are hidden,
8. Use only reliable, proven technology that services your people and process,
9. Grow leaders who thoroughly understand,
10. Develop exceptional people and teams,
11. Respect your network of partners,
12. Go see for yourself,
13. Make decisions slowly by consensus, implement rapidly,

14. Become a learning organization through relentless reflection and continuous improvement (Liker, 2004).

Womack and Jones identified five principles in their works, *Lean Thinking*. Their five principles were based on lean organization of production or delivery; listed as follows:

1. Specify value,
2. Identify the value stream – line up activities which contribute value, eliminate those which add no value,
3. Create the conditions for value to flow smoothly through the stream,
4. Have the customer pull value from the stream,
5. Pursue perfection – work on improving the responsiveness of the production system to the customer demand for value (Womack and Jones, 1996).

Rother and Shook in *Learning to See*, focused on value stream mapping to eliminate waste and make processes lean by following these five steps:

1. Capturing the process,
2. Create the current-state map,
3. Make the stream lean,
4. Create the future-state map,
5. Achieve the future-state (Rother and Shook, 1998).

Each author discussed how to become lean by defining steps or a process to follow. They reviewed the current process; documented the process steps in a value stream map to make the process visible. After the entire process is visible, the problems and/or waste within the process are identified and can be targeted to be eliminated or trimmed from the process, hence the practice of becoming *lean*.

The lean methodology has been applied in manufacturing for years, and the most well known successful implementation has been the reshaping of the automotive manufacturing, specifically at Toyota, where they labeled their lean transformation the Toyota Production System (TPS) (Womack, Jones & Roos, 1991, Liker, 2004,). Liker (2004) spent time at Toyota in the 1980's where he learned how Toyota applied lean to manufacturing. Liker (2008) later expanded lean applications to product development, however; lean applications were not found in Research and Development (R&D) areas.

Rother & Shook (1998), Liker (2004, 2007, and 2008), Womack (1996), Locher (2008), and others have given examples of how to implement lean in high-volume low mix repetitive product industries, such as automobiles and its supply chain, but not of high product mix low-production volume industries. Companies like Herman Miller, Kaydon, and Haworth have applied lean to their process, but they have struggled with strict implementation of lean following TPS. They failed because the rules of takt time and pull cannot be applied in the same way for high product variation and low volumes.

Takt is defined as the customer demand rate per day divided by available working time per day (Rother and Shook, 1996, p. 44). In high-volume low-mix products, takt becomes a very important value of time measurement. The constant volume of the same product lends its self to an easy takt calculation which then the calculations of lead times, process time, and cost all become very easy as well. But with the combination of high variation in the product mix ordered, variation in the complexity product being designed, and variation in the quantities and methods of the parts being manufactured, it creates an unpredictability that does not lend itself to be able calculate a repeatable takt time, therefore, lead time, scheduling, cost, quality, and other traditional lean metrics which are derived from the takt are unpredictable as well. In Custom products takt times are not used. Their lead time, scheduling times, and cycle time are based on historical data of similar type products which vary, but they can be quantified into categories such as Danford (2010) found in applying lean in a custom shop.

a. Lean Applications in Product Development

The elimination of waste and takt time was found where lean was applied to product development processes in the similar manner as they were to manufacturing processes:

1. Create a value stream,
2. Determine the flow and pull, and then
3. Eliminate the waste (Liker, 2004).

The differences found between the two processes were the type of wastes. Product development waste was discussed in terms of recycling designs and testing, eliminating non-value activities that extended the lead times of product to market, and eliminating production costs and quality issues. Waste in manufacturing is comprised of waiting for parts, inventory of parts, and too much movement getting parts, as a few examples. These same methods that eliminate waste in the process, improve the flow, and create pull utilizing a value stream are the same concept that can be applied to custom product development processes.

Oppenheim (2004) lists five steps to implement lean into product development:

1. Define value,
2. Define value streams with takt times,
3. Make flow work with metrics,
4. Create pull and not push systems
5. Pursue perfection.

Oppenheim's (2004) list uses very traditional lean steps to improve traditional product development but does not discuss how to address the takt issue in high-mix, low-volume product development or custom development processes.

Gautam (2005) discusses specifically excluding R&D in his lean product development process. He excludes it because of the constraints of product design variability, which refers to the variability of time, such as how long it would take to prove a design feasible and then to produce it profitably for the mass market. Unpredictability shows up in any new design, therefore, it cannot be controlled and is hard to quantify which creates risk. Gautam (2005) and others such as Chapman and Hyland (2004) negate R&D and concept design from the starting point of their lean or value stream processes because of these risks. These risks include:

1. Unacceptable manufacturing costs,
2. Failure of testing protocols, which require design changes,
3. Recycling of the design,
4. Tradeoffs making the product less marketable or less profitable (Chapman & Hyland, 2004).

These risks increase the time and cost effectively making takt ineffective, therefore, any measurements for lead times, schedules, and cost(s) to be complete at the end of the concept designs is bound to be missed. If the measurements are ineffective, then the methodology is not applied as it is with R&D and custom product processes. Morey (2008) states that the new product development process (NPDP) is not linear. It is cyclic. NPDP placed in a traditional value stream, which is linear, creates problems. He states the value stream must begin after the design has been proven feasible where it is more predictable and linear and it can be measured repeatable.

Concept, innovation, and R&D have been included within the lean product development processes where stage gates discussions were found. Stage gates, developed by Robert Cooper (2008), is a conceptual idea that helped product development move more quickly to production by reducing cycle time with increased quality. Stopping points, or “gates,” were created, wherein the product must pass the reviews at specific gates before being able to move forward into the next phase or stage of the process. The problem with stage gates or reviews is that in the true definition of *lean*, process steps that only add value that the customer will pay for should be used. Processes that do not add value are eliminated. The concept of stage gates adds rigor to processes to ensure quality which adds non-value steps in the process, but establishes a set of requirements that must be met at each gate or step in the process review before being able to continue to the next. The key is to understand what problems are occurring at the gates and eliminate them to eventually stream line, *lean*, the process.

Another lean product development similar to stage gates is a concept called Concurrent Engineering (CE) (Morgan and Liker, 2006; Cooper, 2008) was introduced as a way to eliminate the linear or sequential approach to design iterations by implementing parallel or concurrent paths on designs. This idea starts at concept design gate (or R&D) and was applied to reduce recycling of the design which would reduce the lead time to production. Multiple designs are created simultaneously and the design that best fits all of the requirements is selected to move forward into the product development stage. The idea of CE is to eliminate recycling or modifications of a single design when it did not meet certain requirements. The custom products being design in this process are based off standard product and are not a totally new concept; therefore, concurrent engineering is not applicable for this process but has merit for the standard product.

Nilsson-Witell (2005) discusses five continuous improvement steps for lean product development that involving the people side of lean implementation. They are the following:

1. Create management commitment,
2. Focus on customers and employees,
3. Focus on facts,
4. Continue continuous improvement,
5. Create ownership by participation and involvement (Nilsson-Witell, 2005).

He claims lean or as he called it, *continuous improvement*, is people involved in creating the process goals. His theory was to involve the “people,” in this way making them feel responsible for their own future.

b. Human Element in the Process

Cooper (2008) has stated that people determine if the transformation to lean will be successful or not. Liker (2009) stated that lean is made up of processes and people, and that it is not successful without the involvement of both. Lean changes processes by eliminating waste. Such "wastes" are often changes in the methods (processes) that people have used to complete their tasks many for years. Change affects people differently and it can create anxiety resulting in the person resisting the change. These changes effects were discussed by Johnson in *Who Moved My Cheese* (1998) and they including the following:

1. Fear
2. Stress
3. Frustration
4. Denial.

As with the two mice and two men, they were each affected differently when they found there was no longer any cheese for them to eat. The affects of change that lean brings about must be also dealt with as part of the process to prevent employees from fearful and or frustrated. Liker (2009) stated that without involving people in the lean transformation process, lean may be unsuccessful. Lean must involve steps that involve the people that will remove the fear or at least they will be less fearful of the change. Morgan and Liker (2006) compiled a list of several characteristics that ought to become part of an organization's culture if it (the organization) wishes to create its own lean custom product development system:

> technical and engineering excellence must be highly valued, the culture must be based on discipline and a strong work ethic, improving though kaizen every day must be engrained in the way to do work, everyone involved in the development process must have a customer-first sprit, learning as an organization must be

engrained in the company's DNA, individuals must be willing to stand up and take responsibility when things do not go well, investing in engineers and treating them like valued assets must be the norm, all engineers must step up to challenges as a matter of course, strictly following the right process for doing the work must be highly valued, mistakes must be viewed as learning opportunities, and leaders must be the culture bearers and lead by example every day (Morgan & Liker, 2006, p. 238).

Chapman and Hyland (2004) discussed an approach to create ownership to help with success. Chapman and Hyland (2004) listed four behavioral steps:

1. Human resource policies,
2. Management to manage and handle issues,
3. Performance metrics,
4. Social activities in their lean product development journey.

They suggested that the key to speeding new products to the market is knowledge systems and the process of creating innovation. They believed that creating a knowledge-sharing environment would create ownership of the product and the process which then create an empowering successful work force (Chapman and Hyland, 2004).

Ruy (2008) discovered from his Brazilian manufacturing companies' case studies that lean transformation will be unsuccessful without the involvement of the team. He argued that the transfer of knowledge such as the lean transformation is an organization learning process which takes involvement to learn. Ruy (2008) found that transfer of knowledge was better in one of three companies he interviewed. He found that product development teams whose members do not have offices or desks together and who conduct business in separate buildings often have separate responsibilities that pull them away from the project focus, detracted the members from the learning process. Ruy (2008) also found that projects that involved team members who were only part-time, these projects were not as successful. Ruy (2008) found that the team members who's goals and metrics did not include the success of the product being developed affect the overall success of the project. Ruy (2008) claimed that the overall involvement and commitment levels to change were directly related to the success of the project.

Cooper (2008) stressed that the knowledge sharing and transference could not be just from engineer to engineer but needed to be from customer to marketing, marketing to product development, and product development to production. The process must create a holistic framework and approach, articulated by Oppenheim (2004), including the involvement of all members of the team. Corso (2002) created a virtual concept design model to be able show other team members and customers concepts. The visual model allows the customers and the teams to rally around the models, critique them, and solve problems.

Ruy (2008) also found success on teams that had effective corrective action loops. As new products are needed and new teams are formed to develop these new products, these new teams often "reinvent the wheel" all over again because the lessons learned from the previous team were not transferred to the new team members or actively incorporated into the process. There is no active corrective action loop in product development, but when the process does integrate lessons learned back into the process (a closed loop process), lessons will be learned and shared; thusly, then creating an efficient/ corrective action process or system.

c. Gaps in Applying Lean in Custom Product Development

The solution for custom product development companies to improve their processes is not to just apply what they have learned in traditional lean implementations, but to think beyond it. The concept of flow and pull systems and the idealism that lean can be applied as "one-size-fits-all" (Danford, 2010) is not applicable. Industries must be able look beyond traditional lean to help them to standardize or quantify variability in unpredictable environments such as custom products (Danford, 2010). The variations in time and effort in research and development's or custom product's unpredictable processes have typically kept these types of projects out of scope of lean. These types of projects though can be standardized. Projects must be evaluated in a unique way that will quantify variation and create performance metrics for the team (Huang, 1998; Gielingh, 2008). These types of processes are still standardized and are done by utilizing value stream maps and process flow that are improved by eliminating the waste within them, just like Liker (2004, 2007), Rother & Shook (1998), Womack (1996), and Locker (2008), industry leaders in applying traditional lean.

In an unpredictable process, lean is still used to create standardization and quantification, by it is done capturing the specific repetitive tasks completed by the group members as they are performing their jobs even though the output of the tasks maybe different each and every time. These repetitive tasks are used to create standards, standard work, which also captures the typical time element to complete that task (It is not a takt time but the typical time to complete the time or referred to as the *cycle time*). The standard work time element then helps create a means to measure performance such as productivity and create accountability within the process introducing a human element into the lean process as well.

In product development process it was found that a corrective action loop was often missing as part of the process. A corrective action loop introduces solution to issues back into the process by introducing a method to eliminate errors the plague the process consistently. The issue is then eliminated. NPDP teams that have launched a new product often deployed to another new product before implementing their lessons learned back into the process, but by creating performance metrics for the entire process, it will measure the process to know when it is measuring off target and the individuals are held accountable. It is the best interest of the individuals to share and implement the lesions learned, thus supporting the corrective action loop.

Lean can be applied to unstable and unpredictable process. The approach is beyond traditional lean and does not use standard use of takt times. This non-traditional methodology can be applied to high-mix, low-volume environments as well as to custom product development to create efficient and profitable results in variable processes. The approach includes human elements to successfully implement change as well as incorporating learning/teaching feedback back into the process to provide a measurement of the change. Liker (2007) indicates that lean will not be successful without the transformation of both people and processes; therefore, the human elements of the lean transformation process are also included in applying lean to the custom development process.

III. Approach

To improve the custom product development process, the approach used was the standard five steps of lean as practiced by Liker (2008), Womack (1996), and others were used in addition of a sixth step, a continuous improvement or corrective feedback loop step. The six steps that were used are the following:

1. Capture and create a current process flow map,
2. Capture and create balanced metrics
3. Identify the waste or non-value steps,
4. Create future state process flow without the waste,
5. Identify projects to bridge gap,
6. Continuous improvement or corrective feedback loop.

The first step stated is to capture the process flow of the current process. Companies that are International Standards Organization (ISO) compliant must have their processes documented along with its metrics. The company studied is ISO compliant; hence, this step is complete. However, the documented process needs to be verified that it is the actual process being followed. Past experience has shown that processes can have hidden factories and /or workarounds that are not documented, but are followed by the employees in order to get the work done (Smith, 2010). These hidden factories and/ or workarounds need to be identified and documented. A hidden factory is a correction or rework process that is imbedded in the process because it was not completed right the first time. A workaround is a process utilized when bottle necks are present or when problems occur during the process that is easier to follow than standard process.

The second step, is validating the metrics of the process are balanced and then are added to the process flow map thusly creating what is called the current state Value Stream Map (VSM) (details on how to create a VSM and its icons are found in Appendix B). If the metrics are balanced, they will reflect the input requirements of the next steps and be time-based. These measurements also will be directly related to the end's overall results. For example, the performance metric of an individual needs to not only measures the time it took to complete a given task, such as completing and releasing a drawing on-time, but the quality of the drawing as well.

The third step is to identify waste in the process to eliminate such as eliminating steps that are redundant or do not add any value. Shook used VSM in his lean executions and state values as:

> "A value stream is all the actions (both value added and non-value added) currently required to bring a product through the main flows essential to every product: (1) the production flow from raw materials to the arms of the customer, and (2) the design flow from concept to launch" (Rother & Shook, 1999, p. 3).

Value added activities are desired and non-value added are eliminated to streamline the process which leads to the desired state of the process.

The fourth step is creating the future-state VSM. The future-state VSM is "ideal" state which has no waste within it and includes goals and metrics that support the business and customers with improved lead times and improved quality.

The fifth step is to generate ideas of how to move to the future-state VSM by populating the current-state map with kaizen burst cloud symbols. A kaizens burst cloud signifies that an idea has identified to help the process within that process step. The idea would be implemented through the practice of kaizen events (an event can be a problem solving event to implement standard work to eliminate defects and standardized the process). The kaizens burst clouds would be prioritized and worked on kaizen by kaizen.

The sixth step is to create a continuous improvement cycle. As kaizen projects are implemented new problems and ideas are generated to continuously populate the current-state VSM create an endless cycle to move the process to perfection, the future-state VSM.

The last and final step which is not a lean process step as listed but is a step to compile the process in order to share how to the transform a custom product develop process in order to become lean.

IV. Methodology

This research began by reviewing the custom product development process for a furniture company with $1.3 billion dollar in sales, of which 5-10 % is in custom products. The company also is an International Standards Organization (ISO) certified company; therefore, it had a procedure called the Department Operational Procedure (DOP) 20.00 that documented the custom product development process. DOP 20.0 was a generalized high-level step-by-step process map and it was used as the starting review point. The DOP had one problem. It did not contain the entire process the Request for Quote (RFQ) portion; therefore, the portion missing was created along with reviewing the process for accuracy of completion.

To discern whether or not the (ISO) documented process was being followed; fifteen to twenty custom product orders were followed (tracked) through the custom development process. It was found that the custom product development process actually was found to start at the RFQ stage, the missing portion. However, only 33% of RFQs actually end up as an order. To be more time efficient, order tracking started in the second stage, processing of the order, to eliminate wasting time tracking an RFQ that would never become an order. Though, orders were circle back into the RFQ process to capture the entire process.

Key things sought while tracking orders were if there were any trends or reasons why only 33% of inquiries became orders, if there were workarounds, hidden factories or alternate paths followed and if there was why they were used. After tracking the orders and all paths were captured, a process flow map was created that included flows of the actual process being followed.

Being ISO certified the company would also have internal published metrics. These metrics would be reviewed to determine their ability to measure the process steps and their relative correlation to overall goals or results of the process. As the orders were being tracked, the existing metrics outputs were examined for balance and relatively as an accurate input to the next process. For example, the individuals of on-time performance responding to RFQ directly related to the ability for manufacturing to produce an on-time delivery. If the RFQ is late, the will be order late, therefore, the performance metric must contain a measure of time to ensure the customer on –time delivery. There also needs to be an element of quality performance, to make it a balanced metric, both on time and accurate.

With the fifteen or more product orders tracked throughout the process, the actual process followed was documented. The metrics of the process were also reviewed and changed to create balance and relativity to the process step. A VSM was created from the process flow and its metrics, calling it the custom product development's current-state VSM.

From the current-state VSM, a process without waste is created by the department depart called the future-state VSM. The future-state VSM becomes the platform of the long term goals of the department. The department then identified gaps between the two VSMs and generates ideas how to bridge the gap by eliminate waste. These ideas are populated on the current-state VSM by Kaizen burst clouds symbols. The ideas are prioritizes and the department begins conducting kaizen events.

Kaizen events involve the people who are a part of the process being affected. The kaizen events use leans tools such as problem solving tools that identify root cause of problems in ordered to address the root cause and permanently eliminate it. Kaizen events also provide tools and methods that engage the department to standardize processes such as standard work. All these tools are used to create an environment that continuously looks for means to eliminate waste for the process to eventually to follow the future-state VSM. The practice of continuously searching for improvement ideas and implement the ideas is called continuous improvement cycle.

V. Application

Before starting applying lean to the process, a basic understanding of the process and its current tracked metrics must be known to get the "big picture" of process and its potential issues. To start the department operational procedure DOP 20.0 which can be found in Appendix C was used.

a. Process Flow

The DOP shows individual detailed task being completed by seven color-codes designating seven different job tasks as shown in the legend. What these seven job tasks did to complete a custom product was the first step to understand the process flow.

The DOP along with the department personnel was used to create a high level process map. The DOP was found to be missing half of the process. The DOP only contained the process from the time the customer placed an order. There is another process before the ordering of the custom product called the Request for Quote, RFQ portion. This part of the process is where the product's cost, lead time and its feasibility to even produce is determined, a critical portion of the process; therefore, will be part of the process study. Both the DOP portion and the RFQ were then generalized into eight higher level job task flow categories. The scope of the project contained these eight steps.

Process I, the RFQ portion, has three high level process steps as shown in Figure 1.

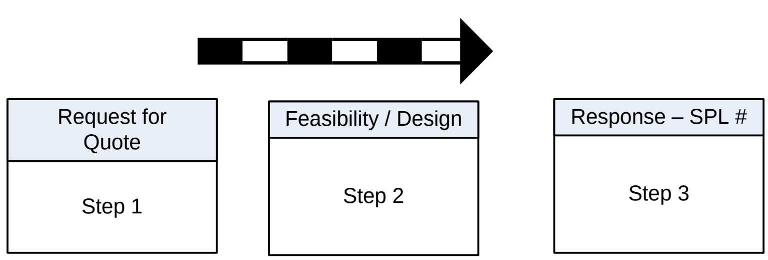


Figure 1: Process I, the RFQ process side of the Process

At the high level, the process begins when a customer submits an RFQ, which is completed and submitted electronically (Appendix D). The first thing is the product being request is reviewed for feasibility. Feasible means the product requested can be designed and produced within the manufacturing limitation as defined early in the definition of a custom product. If feasible, it is quasi-designed, priced, and assigned a custom (referred as a “special” at the furniture company, in reference to a specially design product) part number to it with the prefix SPL, the first three letters, which is given to the customer as well as being stored in DNet (Electronic storing/inventory system). Quasi-designed means the standard parts that are altered and or used were identified to make the custom product, but the actual design shape, dimension, and method of assembly are not. This was done to create an estimated selling price (Cost to produce, material cost, and the profit margin). The lead time of the custom product is also determined based on its complexity and the product type, systems product (standard chairs, metal and fabric wall units) or wood product (Products made from 90% wood construction).

Process II, the DOP portions of the process, consists of five steps including the shipment to customer. The shipping or actually delivery of the product is considered out of scope but Process II metrics are based on customer feedback that is not given until delivery. The scope of the Process II will be on the four steps prior to delivery as shown in Figure 2.

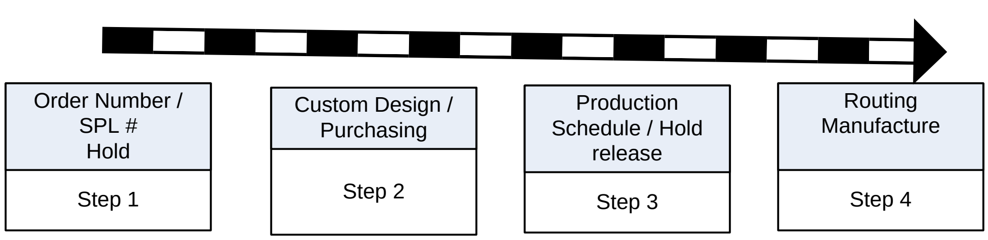


Figure 2: Four Process Steps of Process II

Process II begins when a customer submits the special part number assigned during the RFQ portion for internal tracking of the RFQ, into Comstar. Comstar is the ordering system in which both custom and standard products are ordered (Example: Appendix E). Standard products are then automatically managed by the Enterprise Recourses Planning (ERP) system, whereas, custom products must be manually managed and is placed on “Hold.” The custom order is assigned a manufacturing location. The manufacturing location is assigned based on the similar standard product from which is designed from manufacturing location. In step two, a designer with specific knowledge of that manufacturing plant, would take the order from his or her queue and create the necessary drawings, complete Bill of Materials (BOM) work as required, complete the Engineering Change Order (ECO), and order any required material. After the release of the ECO, routings are added and the hold is released. The order is passed on to manufacturing where it is scheduled for production, which is step three. The product is then produced, step four, and shipped to the customer, step five which completes Process II.

b. **Metrics**

The metrics of the high level process must also be known. In Process I, the RFQ area, there was one performance metric tracked and it was the response time of the quote back to the customer. The goal was that 95% of quotes be returned to the customer within twenty-four hours (one day) for a systems product type and three days for a wood product type. As of September 2010, the RFQ performance measured 60%. Other data was collected as well such as there was an average 607 requests per week. Of these, 20% was deemed “not feasible,” and 1% was canceled by the customer within 24 hours, resulting in a rate of 21% unproductive time (or waste) spent on responding to a RFQ that did not result in quote.

Process II had few performance metrics that were tracked. One quality metric called an "FPR," Field Problem Report (FPR) which is broken down into design or manufacturing errors. The Cost of Quality (COQ), the backlog, and the document completion on-time rate are the other measurements tracked.

A FPR as it is called is an acronym of quality system in which the data is drawn. An FPR is the only means of tracking field problems back to the company; though the FPR system is flawed (FPR is measure as the number of issues per 100 orders). The flaw is that no matter how many issues there are within an order only one FPR will be reported for the entire order. To help explain, an order could be composed of a single item or unit, such as a chair, or it could be an order composed of many items or units, such as the thousand-piece order for the New York City example, and the order can be made up of custom and or standard product; therefore, the measurement of an FPR does not carry equal weight from one order to the next. This methodology of tracking quality issues made it very difficult to differentiate the degree of any one the quality problem, but it was the only quality metric the company had and these quality measurements, broken into design and manufacturing were 0.07% and 1.36% respectively for the month of September.

The cost of poor quality (COQ) was also used as a metric to quantify quality. It was a better metric as it was more relative to cost and scale of issue. For example, COQ measures the FPR (the replacement cost) over the total dollar amount of the order. It still uses FPR data but gives it more in a relative scale. The cost per FPRs per the total sales dollars of all the orders for the month of September 2010 was quite small, at 3%. Though 3% appears to be relatively small, it contributed to over six million dollars in losses each year, and the 3% did not include any quality issues other than customer quality.

The number of orders waiting queue waiting to be processed was one metric tracked and this measurement was called the backlog. The backlog is shown in Process I because it has been not recognized being in Process II yet until a designer begins working on it and the backlog for September was 90%.

Documentation being on-time was another metric. The designers are given three days to complete the design and all its documentation; meaning the ECO to release the product is complete. In September, the documentation was completed on-time 96% of the time in which was above the goal of 95%.

Other manufacturing qualities issues such as the rework and scrap were not captured because these issues were not tracked. They are buried in the productivity numbers in which custom product is not differentiated from standard product either; therefore, the productivity of the custom process could not be used in this paper.

The measurements of the custom process were limited because the company chose not to track custom products specifically and allowed them to be embedded in the standard process (caused inefficiencies and productivity hits but assumed would be absorbed), but those that were tracked were added to the process flow to create the scope and the current metrics of the process to apply lean methods as shown in Figure 3 of the VSM of the Custom Product Development process.

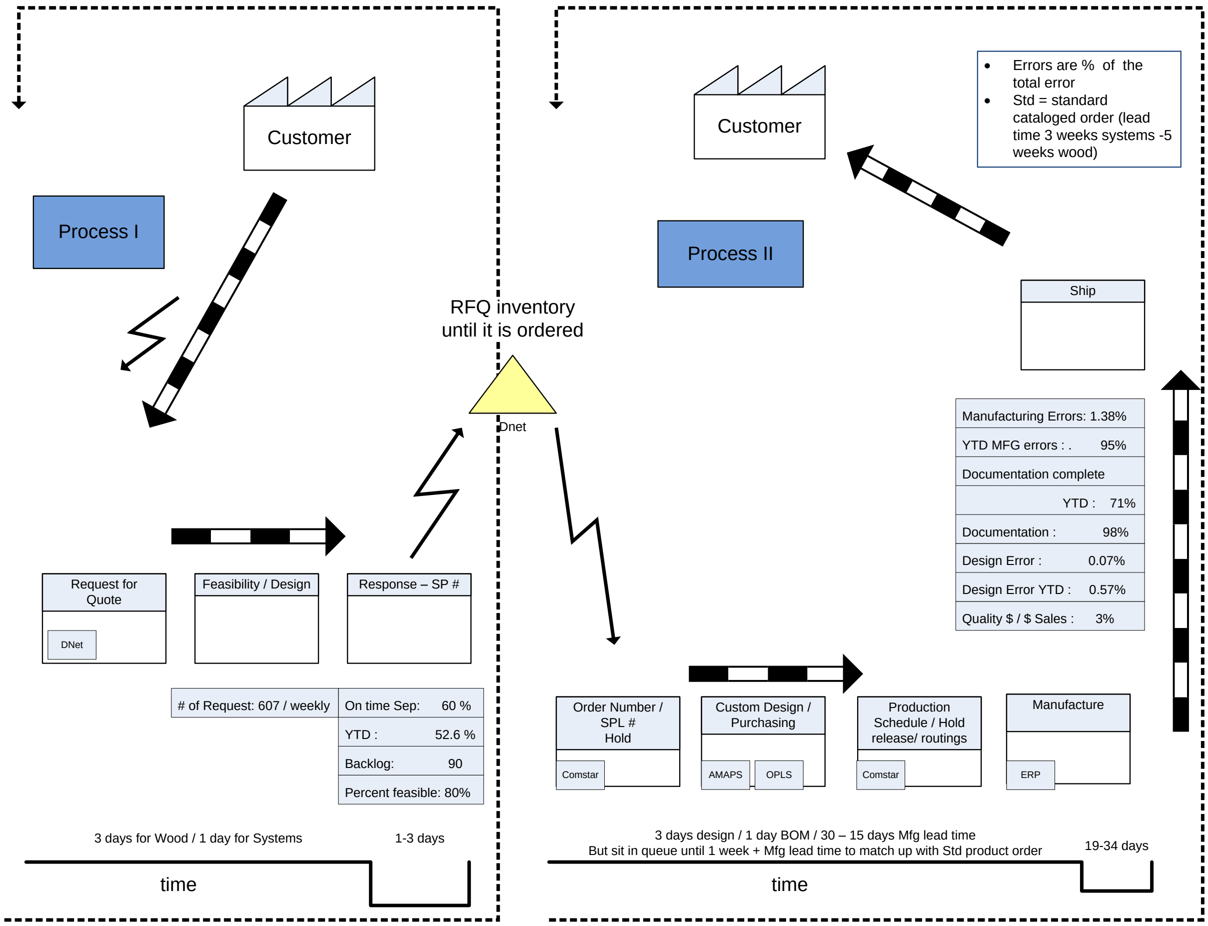


Figure 3: VSM of Custom Product Development Process

c. Creation of the Current-State VSM

With the scope of the project clearly identified, step one of the six steps began by following twenty-one orders over a three month time period, chosen randomly, through the process. These twenty-one orders were followed to capture the full details of the process, including rework, workarounds or additional steps not documented or even steps skipped. By documenting the process actually being done verses the process assumed being followed, the waste in the process can be made visible.

The following of the twenty-one orders began in Process II, step 1 when an order is received. As described earlier, a *designer* will take an order out of his or her queue to begin work completing the design. There were four designers who designed the twenty-one custom products in this study. These designers were interviewed; their job tasks were witnessed and documented in a process flow map. Questions were put to the designers, such as why they performed a specific task, what roadblocks arose, if any, and how they eliminated or worked around the roadblock(s). They were also asked what their performance metrics were and if they had any improvement suggestions to improve the overall process as well.

It was found, that DOP 20.0 differed greatly from the actual tasks completed. The DOP was missing certain steps such as the referencing of other similar designs to copy and paste. There was a custom matrix folder that held all custom products previously created. Whenever a new design was created it was saved in the folder to reference the design in order to save time recreating designs if a similar design was already created (example page: Appendix F). The designer would copy and paste the similar design, then make changes to it, and then save it in the matrix folder. It was found faster than starting from beginning from the standard product. A second step found was that veneer designs were submitted into Integrated System Manufacturing Integrator (ISMI) program. ISMI is a program which was used to create parts sizes for cutting. Both these missing tasks made up two steps the designers did on every order tracked in this study.

After the designers' tasks were documented; a detailed process flow chart was created to show the steps they actually completed in doing their tasks versus following the DOP (shown in Appendix G).

The last step the designers did was to submit the ECO they created to release the drawings and BOM for production, but before the ECO is finalized, it is submitted to a Bill of Materials (BOM) *technician*. The BOM technician tasks are to review the ECO for quantities, assign it part usages, and submit a purchase order to fulfill the demands required within the ECO. After BOM technician completed these tasks, the ECO is deemed complete and it is released, meaning the drawings and the product's BOM are released to manufacturing to schedule a manufacturing date. The tasks of the BOM technician, along with the next two steps, were not called out on the DOP. The DOP called out for a "coordinator," but the tasks of the coordinator were not documented as to what they specifically were.

The next step in the process included the capturing the task of the "routing," the assignment of labor and/or equipment through manufacturing to make the product. The *routing technician* adds the required routings, configurations, and time information into the system along with packaging requirements to be able to ship the product. The routing technician used a reference sheet (Appendix H) to use as a guide. The last step before producing the product is scheduling the product. The *master scheduler*, manually enters the product into the Enterprise Resource Planning (ERP) system, plans the manufacturing date. When the materials arrive, the custom product is then manufactured and shipped to the customer concluding Process II.

On the RFQ side, Process I, there was no procedural documentation on record to compare, so the process was documented as the tasks were witnessed. Process I starts when a customer or dealer submits an RFQ into DNet an example is provide in Appendix D. The *inquiry technician* reviews the particular request by pulling the referenced standard product (Appendix I) used in the request. The technician verifies its feasibility by referencing a lookup database that holds listings of each manufacturing location's constraints such as sizes and materials. If the product is deemed feasible, the technician assigns it a complexity number (See Appendix J for details on assignment of the complexity numbers) and uses the standard product referenced to be modified for pricing. The cost of the product is determined by using a manual guideline that is based on the complexity of the changes and the base price of the standard product. After the pricing is completed, the technician assigns it a part number the includes the "SPL" prefix and other coded numbers that identify the manufacturing location and sends the quoted product along with its lead time (based on complexity and product type) back to the customer. If the product was deemed not feasible, the RFQ was returned to the customer as *no-quote*, stating the product not feasible.

It was found that other products besides custom products were requested in the RFQ process such as obsolete product. Obsolete standard products were requested because of need to replace or add of another piece into existing office area that had an obsolete product line. The designer would re-activity the obsolete product under as special part number. The price of the product is caused problems. Customers would want the product at the old standard rate and the methodology for assigning the cost did too, but the fact was, it cost more to produce it now. The RFQ process did not restrict customers from ordering the obsolete product creating a loop hole in the system. The loop hole needed to be eliminated because customers would continue to order obsolete product versus order new and even though the process could not presently catch the cost to produce the obsolete product, it cost more just by going through the custom process and more people touching the order.

It was also found that other custom products requested were to mix and match standard product lines that did not dimensionally match up well. The study pointed out problem that was given to product marketing group to solve and is out of scope for this paper.

As a result of tracking the twenty-one orders, detailed process flow maps were created for each process step for each worker's task and position involved in the process. The positions were *designers, BOM technicians, routing technicians, master schedulers,* and *inquiry technicians*. Their detailed process flow maps of their tasks can be found in Appendix G. Other positions involved in the process included a *custom product manager, manufacturing engineers*, and *quality manager*. These positions were not directly involved in the processes but did influence how the tasks were performed because they might have been involved because the order was a replacement order or required details of how design product involving new process in manufacturing.

After completing the tracking of the twenty-one orders through both processes, it was found that the original VSM created needed to change to reflect process actually being completed. The VSM was changed to reflect the high level process flow map as shown in Figure 4 for Process II. Process I, did not change.

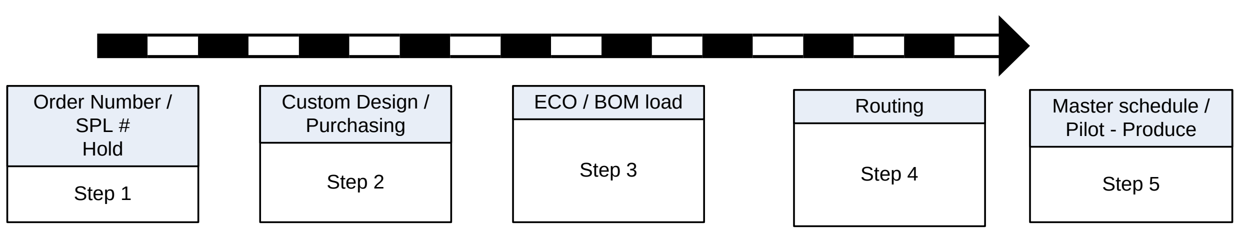


Figure 4: Revised High-Level Process Steps of Process II

The individual tasks within each of the process steps proved vastly different from DOP 20.0 therefore changing the initial VSM created, but now that the actual process has been captured and a process flow documented completing step 1 in the lean process.

d. Creation Metrics for Current State VSM

The initial metrics captured were not balanced metrics; they measured the time, but not the quality of process, but they were the only metrics available. With the new process captured and the inputs and outputs changed, the methodology of balanced metrics must be created and applied to the process.

The proper measurements can be determined from the identifying the requirements and needs at the end of the process for both the customer and the business (Voice of the Customer and the Voice of Business). From there the process is to move up stream, step by step, evaluating each input needs as to be the output requirements of the previous step. The effectiveness of time and quality of that output to the input are the required metrics for that process. These requirements were identified during the interviewing process and following the twenty-one orders. The next step is applying them to the process and seeing if they actually measure the intended requirements; if they are they balanced.

In the Process I the measurement being tracked was the return time. During the study, an inquiry check sheet was found for the inquiry technician to use while completing each quote was found, but it was not used. The check sheet was created to ensure that the information needed by the designer was available to assist him or her in the designing the product. The additional information on the check sheet included such questions as the desired grain direction and if the customer wanted slip or book mark veneer for wood products. Lacking this information, the designers had to contact the inquiry technician, clearly adding time the design cycle.

To add balance to Process I, the inquiry technicians, needed to be held accountable not only for their response time back to the customer, but their accuracy of completing the quote; therefore, their accuracy on the check sheet was added.

As for the metrics for Process II, it was found during the initial investigation of the custom product development process, which began in May of 2010; the department began making simple changes to improve their process. These simple changes affected the process being studied, but just slightly. One change was the introduction of conducting pilot reviews on all new custom products. “Pilot build reviews” are not new and are often used in other industries such as in automotive and are called Final Product Audits (In Automotive, audits were completed on anywhere from 10% to 100% of the product, depending on the stage of the product development and manufacturing process. In the automotive business during a start up, 100% inspection was completed, and during normal production at least 10% or more was inspected). During these pilot reviews, any issue found was corrected, documented and placed into a database called SharePoint, where the information was quasi analyzed and termed First Pass Yield (FPY). The department created this FPY to measure their internal quality metrics because they did not have internal quality metrics and needed them.

From the FPR data from March 2010 to December 2010 as shown in Figure 5, it shows that the FPR data was not directly impacted by the introduction the FPY, “pilot reviews” which began in May 2010. The quality data appears to have no trends, no discernible cycles that would indicate that the audits had any effect on the FPR results, but again, the FPR is a convoluted metrics therefore it might not be able to be detected, so further investigation was needed on the value of the FPY.

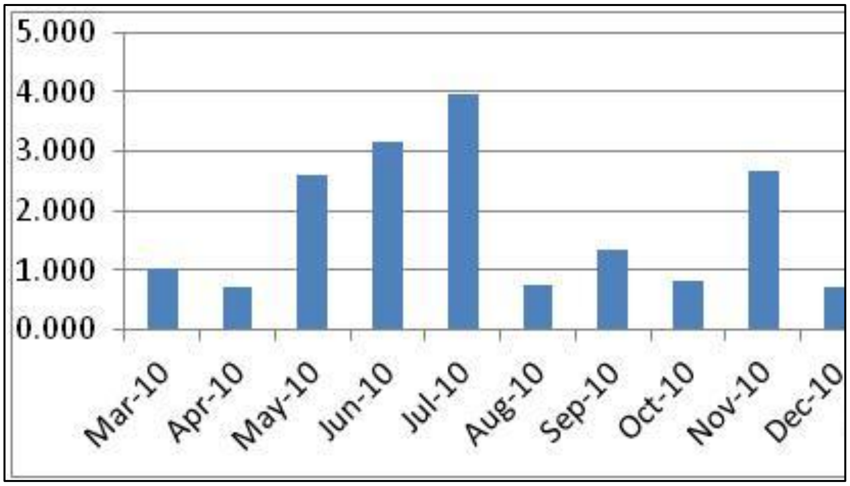
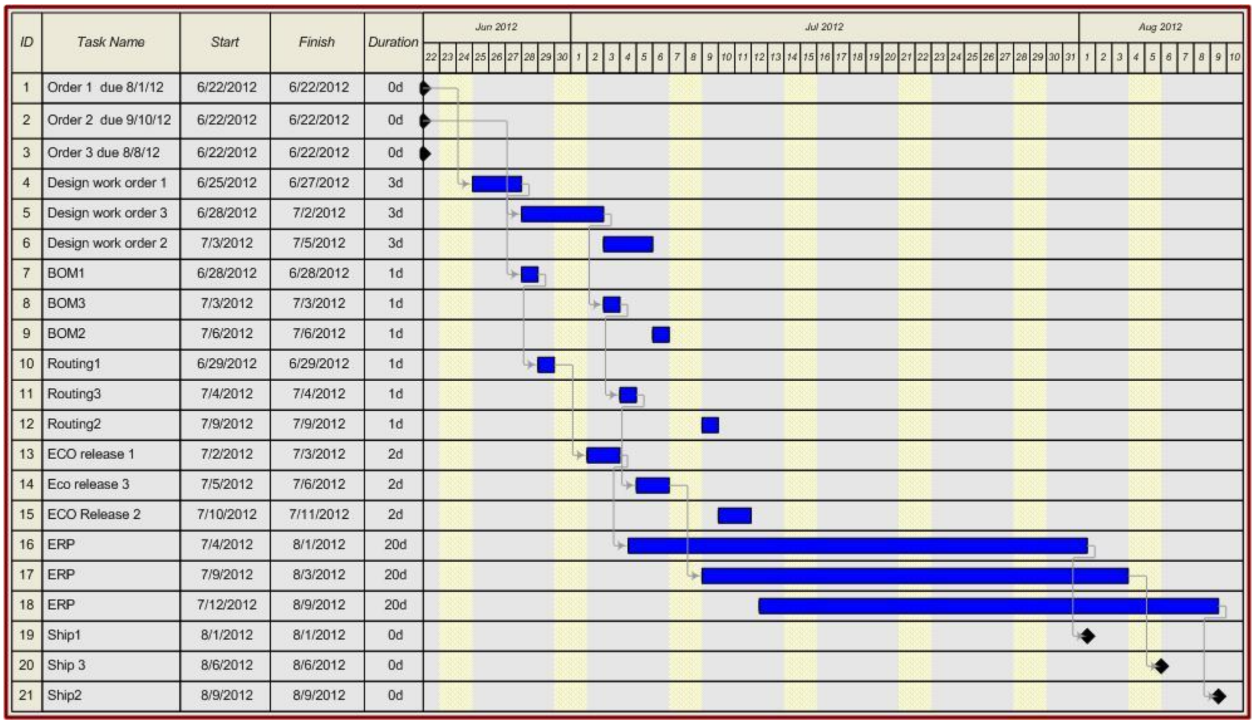


Figure 5: FPRs per 100 Orders for Custom Products from March through December in 2010 Year Tracked by Month

Another measurement of Process II was the documentation completion "on-time" measurement or called document completion-time. The document completion-time was the measurement of the processing time it took a designer to begin designing a product to its ECO completion, including any waiting time. The process gave each order three days to complete drawings, one day to complete the BOM, and fifteen to thirty days to complete the manufacturing process depending on complexity and type (which included routings, receiving parts, and completing pilot, if required). The process already utilized a pull system, which the meant the orders which held in queue until there was one week plus the standard manufacturing lead time, before the designer began designing the product (Orders were pulled through the development and manufacturing process). Orders begin being worked on one week plus the lead time. If there is no other orders in queue, they would work on the other orders that are in the queue. Figure 6 shows a Gantt chart of the how the orders are pulled through the process and are completed relative to their time allotted.



ID	Task Name	Start	Finish	Duration
1	Order 1 due 8/1/12	6/22/2012	6/22/2012	0d
2	Order 2 due 9/10/12	6/22/2012	6/22/2012	0d
3	Order 3 due 8/8/12	6/22/2012	6/22/2012	0d
4	Design work order 1	6/25/2012	6/27/2012	3d
5	Design work order 3	6/28/2012	7/2/2012	3d
6	Design work order 2	7/3/2012	7/5/2012	3d
7	BOM1	6/28/2012	6/28/2012	1d
8	BOM3	7/3/2012	7/3/2012	1d
9	BOM2	7/6/2012	7/6/2012	1d
10	Routing1	6/29/2012	6/29/2012	1d
11	Routing3	7/4/2012	7/4/2012	1d
12	Routing2	7/9/2012	7/9/2012	1d
13	ECO release 1	7/2/2012	7/3/2012	2d
14	Eco release 3	7/5/2012	7/6/2012	2d
15	ECO Release 2	7/10/2012	7/11/2012	2d
16	ERP	7/4/2012	8/1/2012	20d
17	ERP	7/9/2012	8/3/2012	20d
18	ERP	7/12/2012	8/9/2012	20d
19	Ship1	8/1/2012	8/1/2012	0d
20	Ship 3	8/6/2012	8/6/2012	0d
21	Ship2	8/9/2012	8/9/2012	0d

Figure 6: Gantt Chart of the Work Order Process

Figure 7 shows the number of new orders completed or the weekly output. Figure 8 shows the number of orders completed on-time for designers given the three days to complete the design.

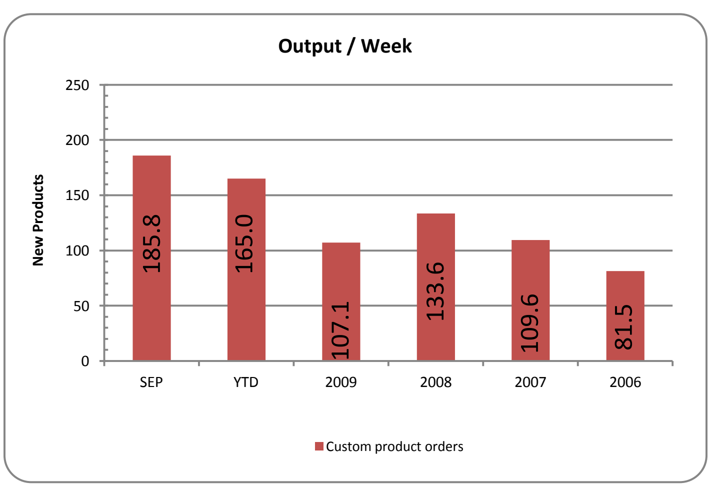


Figure 7: Number of New Orders per Week

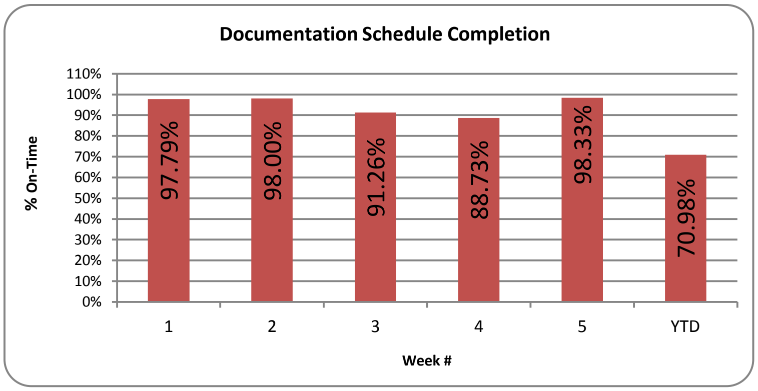
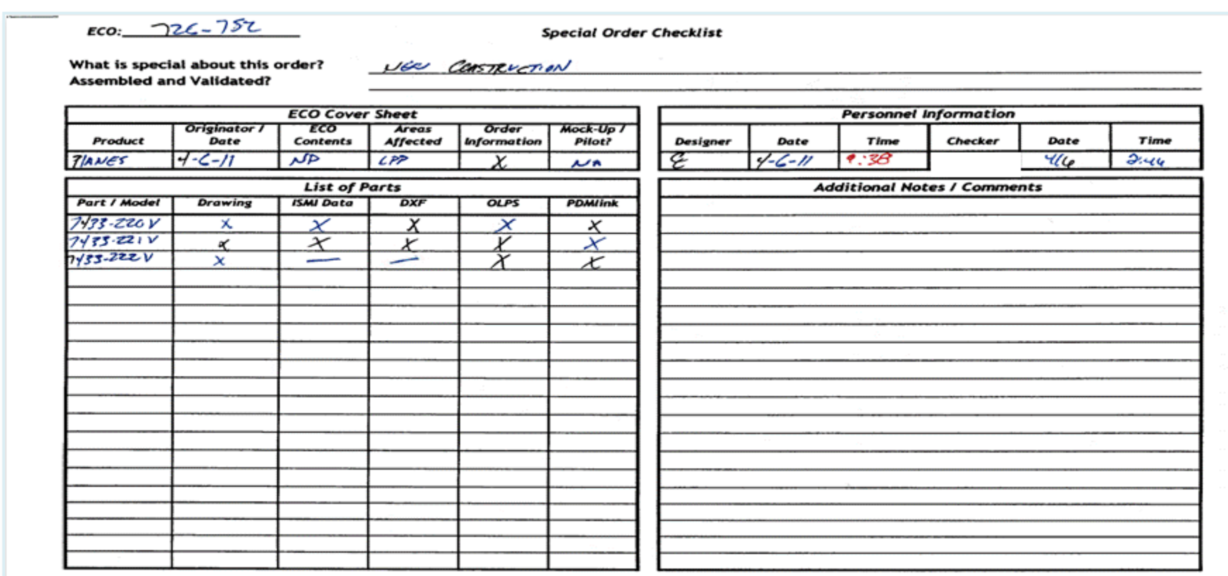


Figure 8: Number of Orders Completed on-time per Week

This existing time measurement was a good metric for measuring designers' time element of the process, but there was no accuracy measurement to create balance. In September of 2010 the custom design manager implemented a checking process of the designers work. The checking process involved reviewing all of the tasks that the designer was required to complete, which was the creation and/or re-release of a custom product which resulted in a completed ECO, step 2 on the VSM. An example of a check sheet is shown in Figure 9.



ECO: 726-752

Special Order Checklist

What is special about this order? Assembled and Validated? NEW CONSTRUCTION

ECO Cover Sheet

Product	Originator / Date	ECO Contents	Areas Affected	Order Information	Mock-Up / Pilot?
PLANES	4-6-11	NP	CPP	X	NA

Personnel Information

Designer	Date	Time	Checker	Date	Time
E	4-6-11	?:38		4/6	2:44

List of Parts

Part / Model	Drawing	ISMI Data	DXF	OLPS	PDMlink
7433-220V	X	X	X	X	X
7433-221V	X	X	X	X	X
7433-222V	X	—	—	X	X

Additional Notes / Comments

Figure 9: ECO Designer Check Sheet Instituted in September of 2010

One check sheet was used per each ECO per order, and a single ECO could have many parts and or drawings depending on the complexity of the part or parts. In the example, there are three parts and three drawings all to make an order. As the design manager checked the sheet, he would place an “X” in the boxes in which the data or tasks completed were found to be correct and a dash (“—”) in boxes which required no information for that part number, as shown. If something was found to be incorrect or missing, the design manager would circle the box in red ink to indicate there was a problem, in addition he would write in the comments area what was wrong and in need of correcting (Figure 9, there was no errors found). The ECO along with the check sheet would be returned to the designer for correction(s) and then returned back once corrected to the design manager for signoff.

Initially the design manager did not use the check sheet as a method for accountable for accuracy and he did not tally or analyze the results; therefore, corrections were made but the same errors were made over and over again. The check sheet results could be used to measure the accuracy of the designers; therefore, was introduced as the measurement for accuracy and was calculated starting in February of 2011. The results are shown in Figure 10.

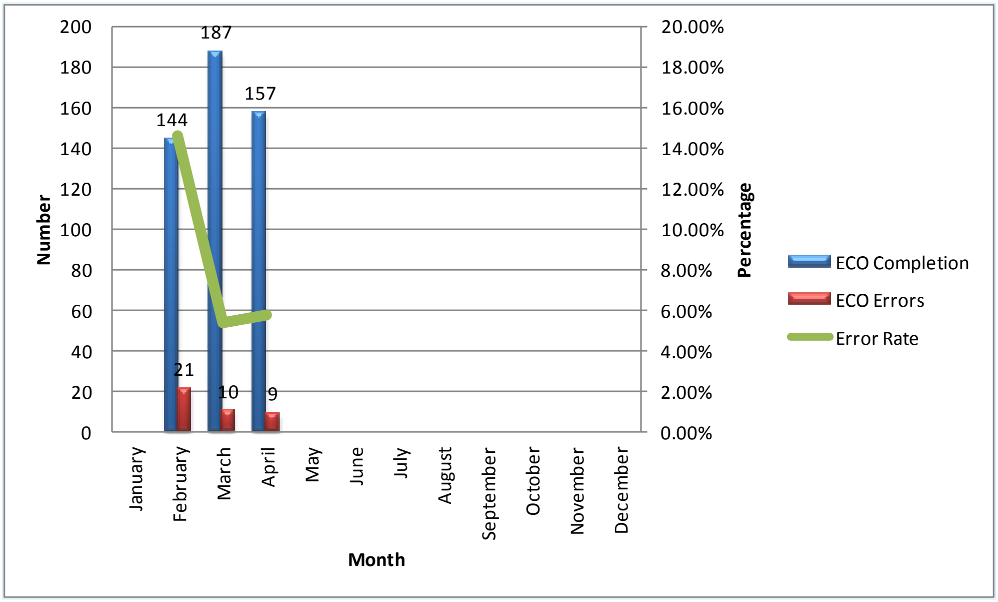


Figure 10: The Check Sheet Data for the Number of ECOs and Errors per Month and the Percentage of Errors Found in the ECO (2011).

The graph of the check sheet results did not reveal any specific trends but did provide a measurement for the accuracy of the work completed by the designer. The check sheet and the documentation completion-time results provide balanced metrics for step 2.

The BOM and Routing Technicians' had no measurements of time or quality of their tasks, but both time and an accuracy measurement were needed for steps three and four. The last process step, step five, was scheduling. The company's ERP system did the actually scheduling within the plant after the materials and labor became available, but the master scheduler was required to balance the load to allow for custom product to fit into the schedule otherwise standard product would fill all availability and to manage custom products in the schedule creating the least amount of disruptions to standard products. The master scheduler's metrics fall as part of the pilot review audit because producing the product is part of the same step. The balanced measurements are the audits accuracy and if the product was produced on-time.

For each process step balanced metrics were indentified, but are these correct metrics? The metrics were reviewed to ensure they reflected the overall desired process measurements and measurements indicated if the process was in or out of control within the process.

e. Metric Methodology

"Good" metrics have direct relationships between the metrics of the individual boxes (input to output) and the overall time and quality performances—both internally and externally to be effective. The measurements identified were reviewed and it was found that the overall measurement methodology needed to change, because they were not "good" metrics.

The First Pass Yield (FPY) measurement created from results of the audit review was a good measurement of the output of step five, but it used by the plants as its overall time and quality which was an incorrect use of the measurement. The FPY measurement was put in place in May and the results are shown in Figure 11.

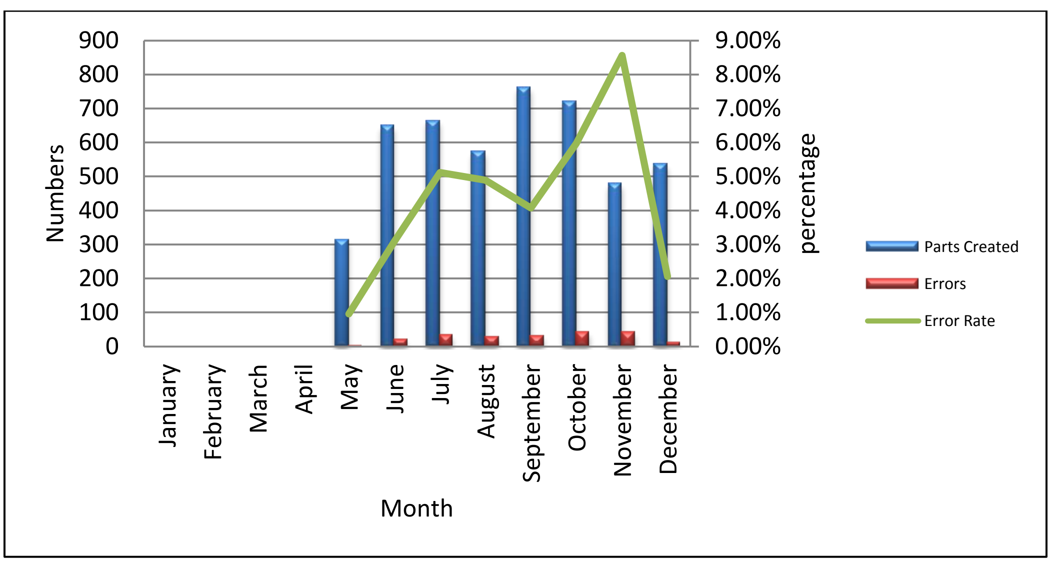


Figure 11: First Pass Yield Data by Month for Both the Quantity of Parts, Errors, and the Percentage of Error (2011)

The FPY measurement created and as it was called was a not truly a calculation of the first pass yield of the process. The definition of First Pass Yield as defined by Lean:

> “First pass yield (FPY) is a metric that indicates the percentage of items moving through a process without any problems. One such problem, of course, is scrap, which makes the output of items from a process lower than the input. But, because many processes have built in rework, simply measuring at the end of a process doesn’t give a true picture of quality. Instead, first pass yield is calculated from the individual yields of each process.
>
> *First Pass Yield = Process 1 Yield * Process 2 Yield *…*Process ‘n’ Yield*
>
> As you can see, it doesn’t take long for defect rates to stack up. For example, four processes with a 95% yield only produce good products without any rework 81% of the time.
>
> One of the challenges in understanding first pass yield is the lack of visibility. Because most frontline workers want to do a good job, they fix problems on the spot, or help out their upstream coworkers. As a result defects are not recorded, inflating the first pass yield rate.” (Velaction, 2011)

The FPY measurement as it was used was incorrect. It only measured process step five and neglected the total yield of the entire process. There are multiply process steps and during each process step there were corrections occurring such as corrections witnessed by the BOM and routing technicians during the job following. These corrections effect the FPY measurement but were not inputted as errors in the calculated; therefore, the FPY calculation is incorrect and the FPY value is inflated due to its improper calculation. To calculate the correct FPY of the process, each step (such as the designer process, the BOM technicians, etc.) would need to be calculated individually, for example, the check sheet results for the designers could be called the Designer First Pass Yield (Dgr FPY). The corrections made by the BOM technician would be first need to be recorded, but then be called the Bill of Materials First Pass Yield (BOM FPY). Those made and recorded by the Routing technician will be called Routing First Pass Yield (Rt FPY). The multiplication of these individual FPYs would then result in a True FPY calculation. The calculation of the True First Pass Yield for this process would then be calculated as shown by equation [1]

$$(\boldsymbol{Dgr\ FPY}) \times (\boldsymbol{BOM\ FPY}) \times (\boldsymbol{Rt\ FPY}) \times (\boldsymbol{PR\ FPY}) = \boldsymbol{FPY} \qquad [1]$$

where:

$Dgr\ FPY$ = Designer First Pass Yield

$BOM\ FPY$ = BOM Technician First Pass Yield

$Rt\ FPY$ = Routing Technician First Pass Yield

$PR\ FPY$ = Pilot Review First Pass Yield

FPY = Final First Pass Yield.

The FPY calculated from equation [1] measures the internal quality metrics and it should correlate to customer quality measurement (FPR possible not because of its inherent inconsistencies) if it is collected and analyzed.

To make the overall measurement balance, the time element is other measurement required to track throughout the process which is the lead time of the process. The lead time contains both value add time and non-value add time initially. The time is not differentiated from waiting, rework or processing, but will need to be to eliminate waste.

With the new metric methodology established, data collection was the next step to populate the VSM.

f. Data Collection

Data collection was gathered from the twenty-one orders were followed through the system, but information on other orders were gather as well. Data collection was not an easy task. As the RFQ evolves through the process, it takes on many other identification numbers such as the RFQ, a order number, a part number or many part numbers and an ECO, in each different database or system it is stored. Because the order was stored as different numbers, it made it difficult to track through process unless it was manually tracked by cross referencing its RFQ number. It was the only numbers that tied the custom product to an order, to part numbers and to an ECO. Though it was time consuming, data collection began.

Data collection occurred between January and March of 2011 on process I that were already in place, no change in process or procedures were completed during this time such as adding tracking of errors and or correction at the BOM or routing steps. As mention previously twenty-one orders where tracked through the process and detail data was collected on them. Other sampling data came from check sheets, pilot review audit results, and the FPR results. All the data is summarized in Table I where it was used to study the overall performance of the entire process.

Table I: Summary of Data without Errors of Orders. FPY, FPR, and Check Sheet Results Collected in January, February, and March 2011

	Jan	Feb	Mar		sampling	21 orders
Orders	199	144	181		136	21
FPY (pilot only)	95.77%	94.74%	96.92%		23.50%	9.50%
FPR (issues / 100 orders)	0.25	0.4	0.7			0.1
Check sheet					47.50%	80.20%

In Table 1, it shows that of 199 orders completed in January, 144 orders in February and 181 in March, its FPY pilot review audit) and FPR results vary month to month. The table also shows a sampling of 136 random orders their respective FPY and check sheet results. The results were calculated by the number of errors divided by the total number of orders within the same time period. The number of errors was determined by giving the order a “single” count of one error even if the order contained more. The twenty-one orders that were tracked had the best customer results, per the FPR data, but they also yielded the worst pilot FPY results. It was possible that everything was caught and corrected before it went to the customer because these orders were being tracked (more visibility placed on these orders) but real reason is not known.

To know what the true FPY, equation [1] was used on the twenty-one orders data. The result were found to have a seven percent (7%) FPY. Its corresponding percentage correct on FPR was 0.1 which is relatively better than the other three months. As previously mentioned, the results could have been due to visibility and any issues were corrected before the product left for the customer.

The 136 check sheets randomly pulled had an average score of 94% correct with a standard deviation of 11. The score indicated that the designers were fairly accurate, but the unpublished goal for the designers was 95% indicating designer were failing to meet their goal and design alone was passing along 6% defects to be corrected downstream or passed onto the customer.

The overall results did not lead to any positive correlation between pilot FPY and FPRs as desired, but with FPR data that is possible because the FPR measurement is flawed. More data collection and analysis, such as the breakdown of the errors and other problems solving tools are needed to improve the process and fine tune the measurement methodology and data collection. But the data collection did provide enough information to complete a skeleton current- state VSM for the application of the proper balanced metrics as shown in Figure 12.

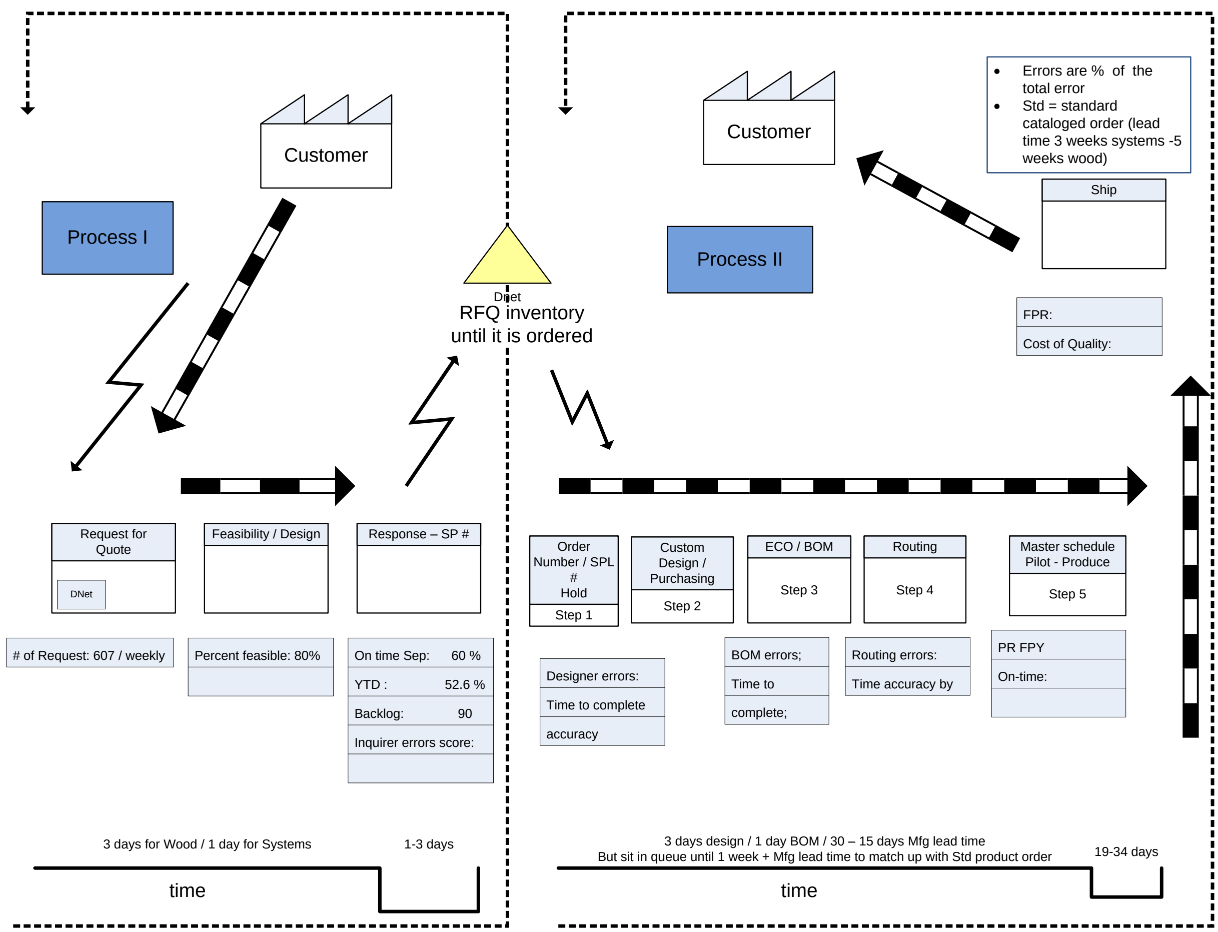


Figure 12: Current-State VSM with Balanced Metrics Applied

g. Identification of Waste

The next step in the lean process is to identify waste in the process. Three wastes were easily identified in the process and they were waiting, defects, and behavioral wastes. The wastes were too broad to specifically eliminate; therefore, the causes or the specifics of the waste needed to be known before they can be eliminated; therefore, data analysis was needed.

The FPY results collected (January through March of 2011) were categorized into error types and these errors types were called: BOM errors, print errors, design errors, and ISMI errors. The categorized FPY error types were graphed and are shown in Figure 13.

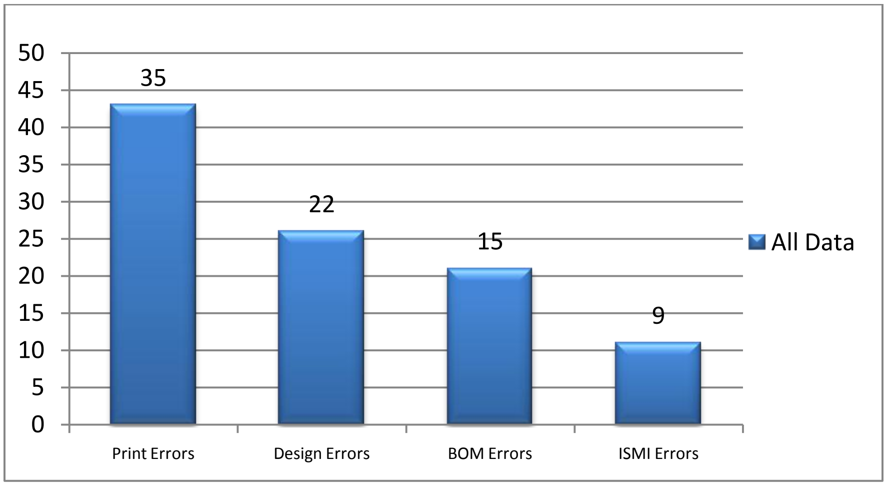


Figure 13: FPY Results Broken Down into the Number of Errors by Error Type
January through March 2011 Data

The error types were then broken down further into pie charts because the specific error was still too broad to understand the problem. The error types were broken down further into four contributors: part quantity, wrong hardware, planks, and edge-band. The highest contributor would be further studied to be eliminated. Also comparing the twenty-one orders, FPY errors to the FPR errors, it was found BOM errors were slipping through the process because one of the orders had a BOM error found at the customer. This FPR BOM error indicates that there is a problem in the inspecting BOMs, because not only was the BOM checked first during the ECO process, it was checked by the BOM technician, and again during the pilot review audit. The BOM is checked three times before the product is shipped, yet an error was shipped to the customer.

Other errors were not recorded during the checking processes, such as the FPR issue of the wrong width (one of the twenty-one orders tracked with details). The check sheet indicated that all work had been completed. The pilot review audit indicated that there was an issue, but it was due to the missing quality inspection of a supplier's part which had nothing to do with its width. It was discovered that the check sheet indicated ISMI data was completed and checked (ISMI data generation is part of the designers tasks and is verified on the designer check sheet, Appendix M), but ISMI data created was wrong. A data file was created, but the dimensions were wrong; therefore, not checked or missed.

The analysis of the errors showed how flawed the checking process was in preventing deflects; therefore, the checking procedures needed to be improved to not only to eliminate the deflects but also the extra work completed both adding waste.

Behavioral waste was another waste found in the process meaning that the members of the department accepting the fact of they had repetition in the same re-occurring errors and the corrected issues on the "Fly" without documenting they occurred. The behavior of the group indicated the group was frustrated with the process; therefore, the reason why workarounds were found (Appendix G) which by passes the normal process which causes defects, extra effort somewhere else in the process, which is waste.

A third waste was found, waiting. One example of this waiting was witnessed when t he designers had one to three active orders at one time because waiting on information back from the inquirer because it was missing in the order file or details required from the customer would be needed because the design details were vague (drawing or sketches were required from the customer, but could be by passed; therefore leaving the design specifications missing) and had to be defined to complete the design. For example, the customer requested a five centimeter diameter hole placed in a desk top for cables, but did not specify where. The designer needed to know specifically where to place the hole and not place the hole arbitrary in the surface or else it could cause an FPR. The inquirer should have seen that the location details were missing and requested it during the quoting process because the location of the hole could cause other issues such as assembly or manufacturing issues if the location of the hole is a critical location and requires alternate design which alters the price and lead time.

h. **The Future-State VSM**

There were three clearly indentified wastes in the process that required elimination, but eliminating these wastes from the process did not change the overall process identified as the current-state VSM with balanced metrics. The new balance metrics methodology that was identified was not effectively put in totally in practice yet; therefore, the current-state VSM with the balanced metrics is the future-state VSM at the high level but it also includes ideas to improve the checking methods.

To get to the future-state VSM, the department had to generate ideas how to get from the current-state VSM, Figure 3, to an ideal state with no waste Figure 14. The creation of the future-state VSM completes step four in the lean process, which leads to the next step of bridging the gap from the current-state to the future state. Lean activities to bridge the gap and eliminate waste are called kaizens.

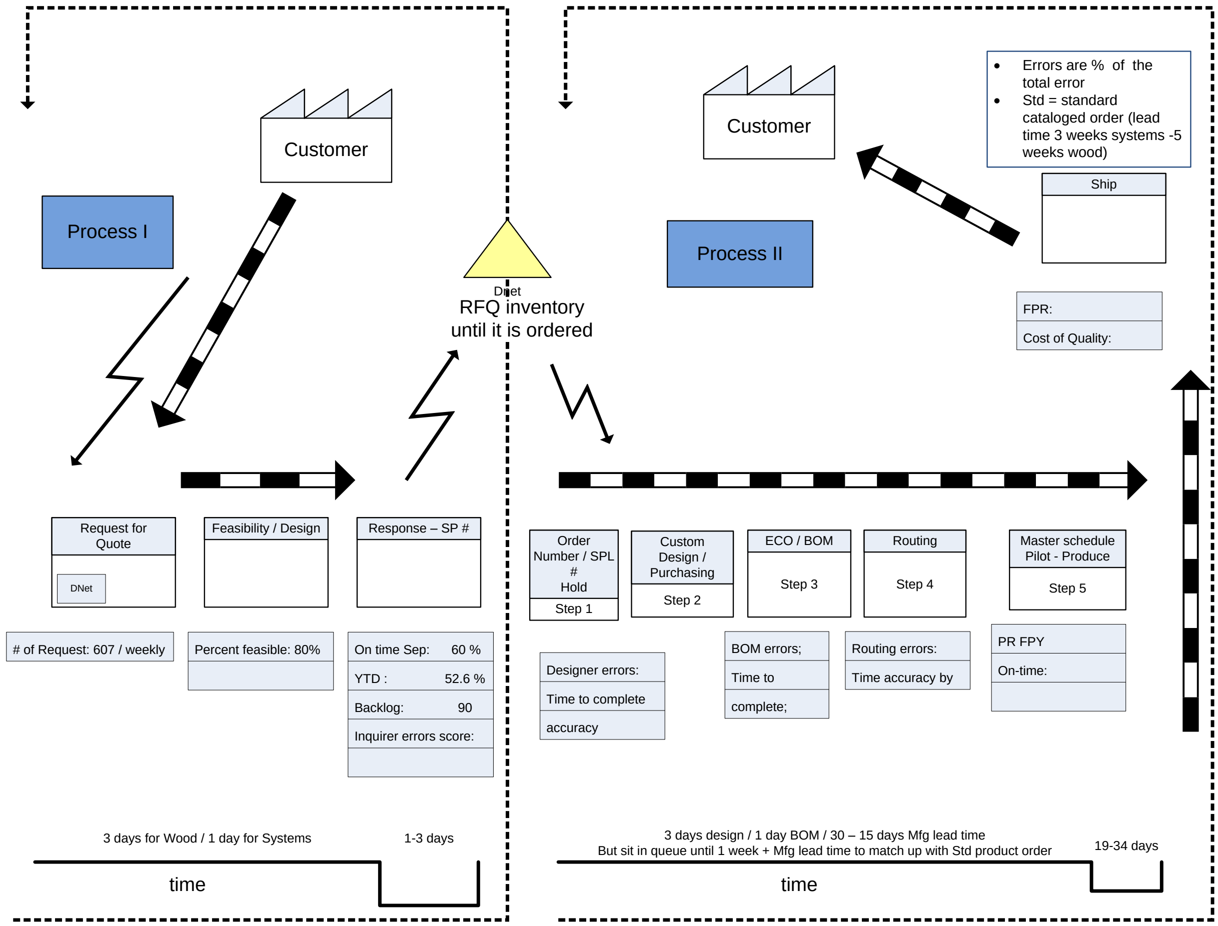


Figure 14: Future-State VSM

i. Bridging the Gap with Kaizens

The fifth step in the lean process is to bridge the gap between the current-state and the future-state and as mentioned, the bridging the gap consist of ideas or identification of an area that needs waste eliminated in that portion or part of the process. These ideas are referred to a kaizens.

Kaizen is a Japanese word by definition meaning "continuous improvement." A kaizen event—an improvement in practice—is an event that focuses on a specific area or topic so that improvements can be seen, felt, measured, and completed by a cross-functional group that has influence over and/or responsibility for that focus area. Kaizens are indicated on value stream maps as yellow burst clouds. The ideas or kaizens, identified for the custom development process are shown in Figure 15 in which the original current-state VSM was used.

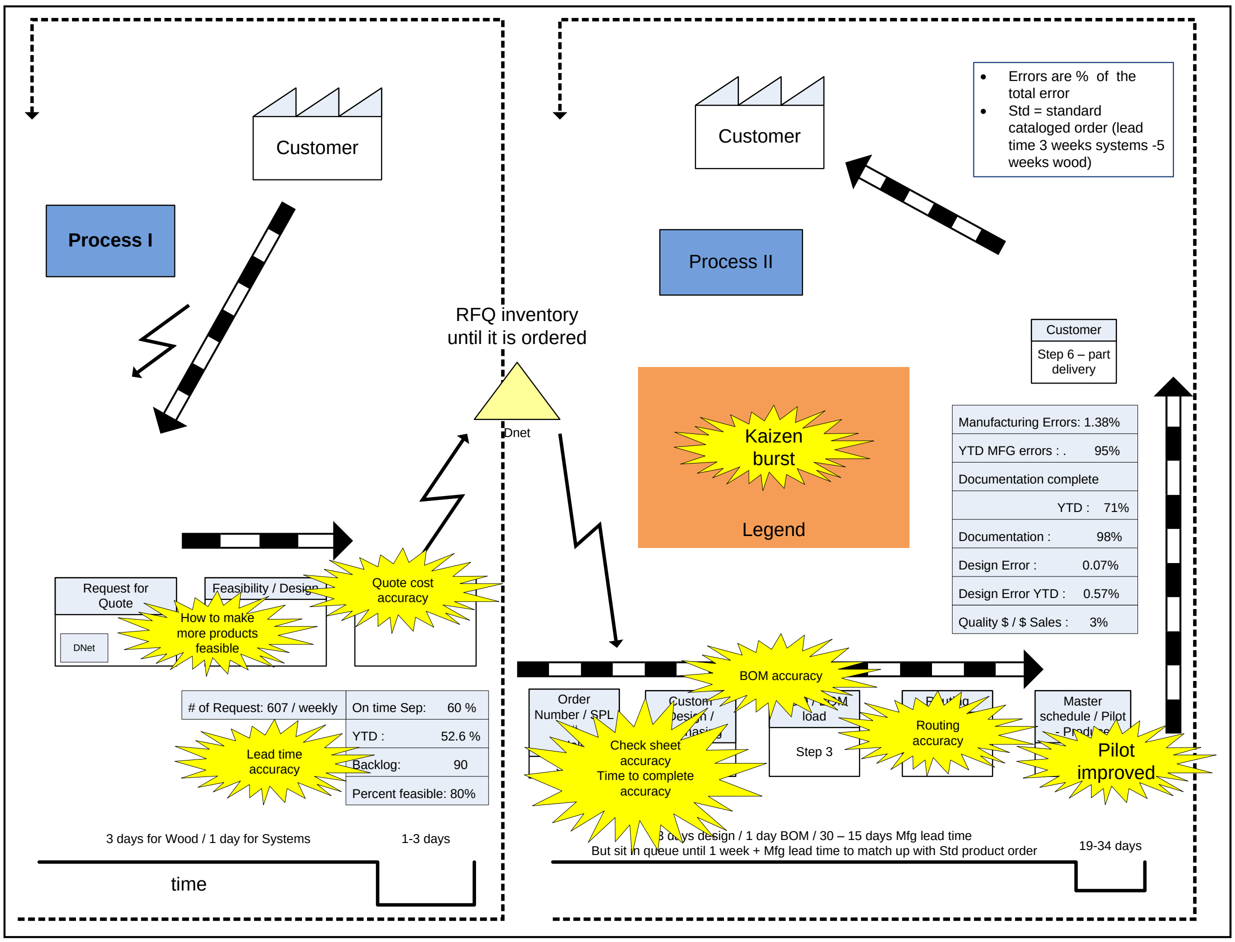


Figure 15: VSM of the Process with Kaizen Bursts

The bursts clouds locations on the VSM indicate where kaizen improvement efforts are needed to bridge the gap from where the current process is to where it needs to be. The text within the burst clouds identifies the needed focus topic. A kaizen event—a weeklong event—is scheduled to brainstorm ideas on the focus topic, prioritize those ideas, and then take one idea and implement it. The idea has to be measured before and after to see the net effect of the change to process. This is done in order to be able to see if the change affected the process, positively or negatively.

Kaizen events are used to drive lean improvements and are used in lean books like those written by Rother & Shook (1998), Liker (2004, 2007), Womack (1998), and Locher (2008). There are published steps for how to schedule, conduct, and document kaizen events (A list of general steps for how to conduct a kaizen event can be found in Appendix E). In the study of this process, there were four Kaizens conducted; BOM error reduction by the designer, RFQ accuracy, RFQ feasibility, pilot review audit improvement. The BOM errors kaizen used many lean tools the first was a problem solving tool to understand the root cause(s) of what was causing BOM errors.

i. Problem Solving

Problem solving includes detail data analysis. The BOM errors types was for example, was one of the highest error types categorized from FPY data as shown in a pareto chart, Figure 16. The data from specifically from the BOM error types was then broken down into smaller error type categories, as shown in the pie chart diagram Figure 17.

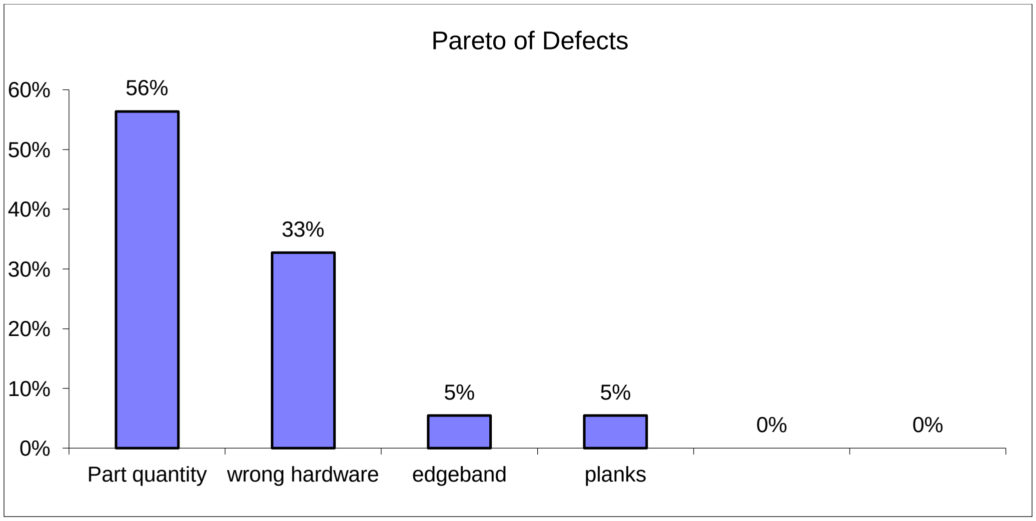


Figure 16: Pareto of the BOM Errors Captured from the FPY Data

(The use of a Pareto chart can display the errors in order of the highest to lowest or in a pie chart, where the slices indicated the largest category by the size of the slice. The error that has the largest slice of should be worked on first. Problem-solving tools and data analysis of the metrics must be used in conjunction with the kaizen events to help understand the problem or waste, to quantify the problem occurring, and to find the root cause(s) to eliminate it. Data analysis is always completed first, in this study it was completed, by breaking the data down into smaller pieces as shown in the data collection section, page 45).

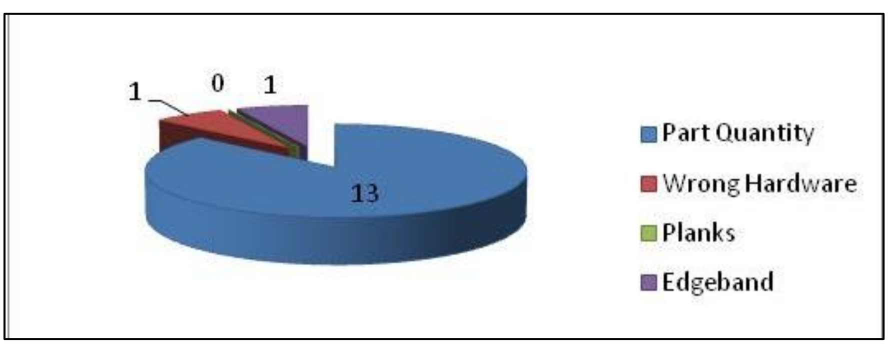


Figure 17: A Pie Chart of the Breakdown of BOM Errors Found in the Pilot Review from January through March 2011

The pie chart shows that the incorrect (wrong) part quantity error was the largest contributor. Therefore, to problem solve why incorrect part quantities were occurring, a fish bone (cause and effect diagram as referred to as well) was completed. Figure 18 depicts the results of the fishbone diagram on BOM errors. (How to complete a fishbone diagram can be found in Appendix K).

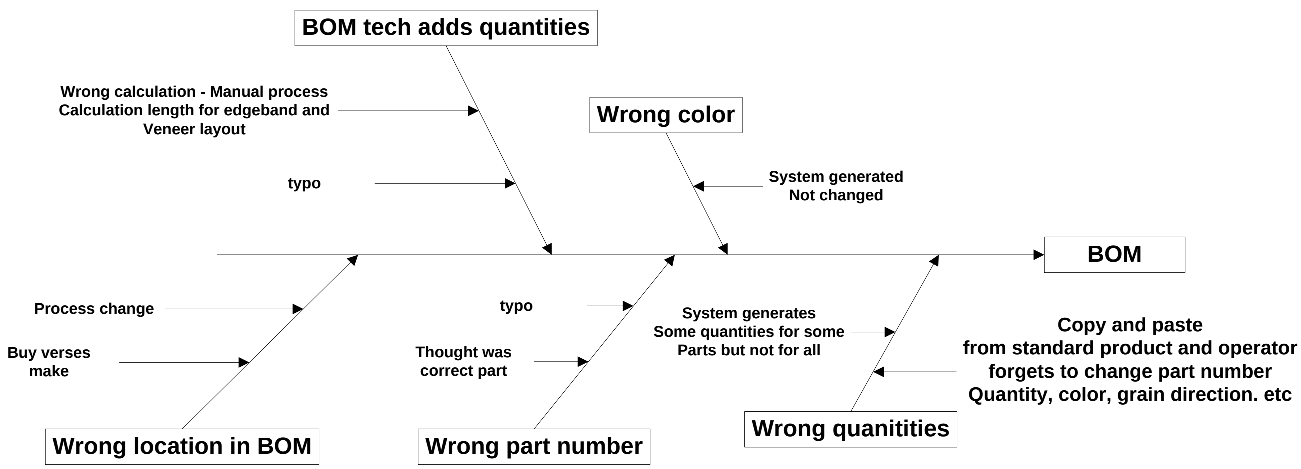


Figure 18: Fishbone (cause and effect) Diagram of the BOM Errors Captured from the FPY Data -- It is used to Identify Possible Causes

(Other problem-solving tools could have also been used to find the root cause, such as the “five whys.” This tool continues to ask “why” until “why” cannot be asked again). The fish bone identified two possible “bones” of the fishbone that contributed to the wrong quantities. The first was the wrong part quantity and it was determined that one of causes was due to the copying and pasting of standard product BOM into the ECO and then altered to the new product. The root caused was determined that the designer forgets to change the part quantity reflecting the new product thus it creates an error for the new product. The second is the BOM technician adding or changing the quantities in which an error is created by a typing or a calculation error. Ideas to solve the wrong quantities were brainstormed and three of the ideas were generated and one was implemented.

The first idea was a creation of a macro that highlighted all quantities within the ECO. The designer was then required to enter in numbers or quantities in the highlighted fields or else the ECO could not be saved until the quantities were entered where the macro. The macro would the count up the number of pieces used and compare to the BOM. If there was a discrepancy, the macro would identify it. This idea required Information Technology (IT) department to be involved and to be approved. The second idea was creating macro that compared the model's parts and number of ECO's part items. The number of parts in the model must equal the number in the BOM and ECO. If not, there is an error. This idea also required IT involvement. The third idea was to create standard work that the department was to follow that including a second check of the part quantities. This idea only required the group's involvement and time.

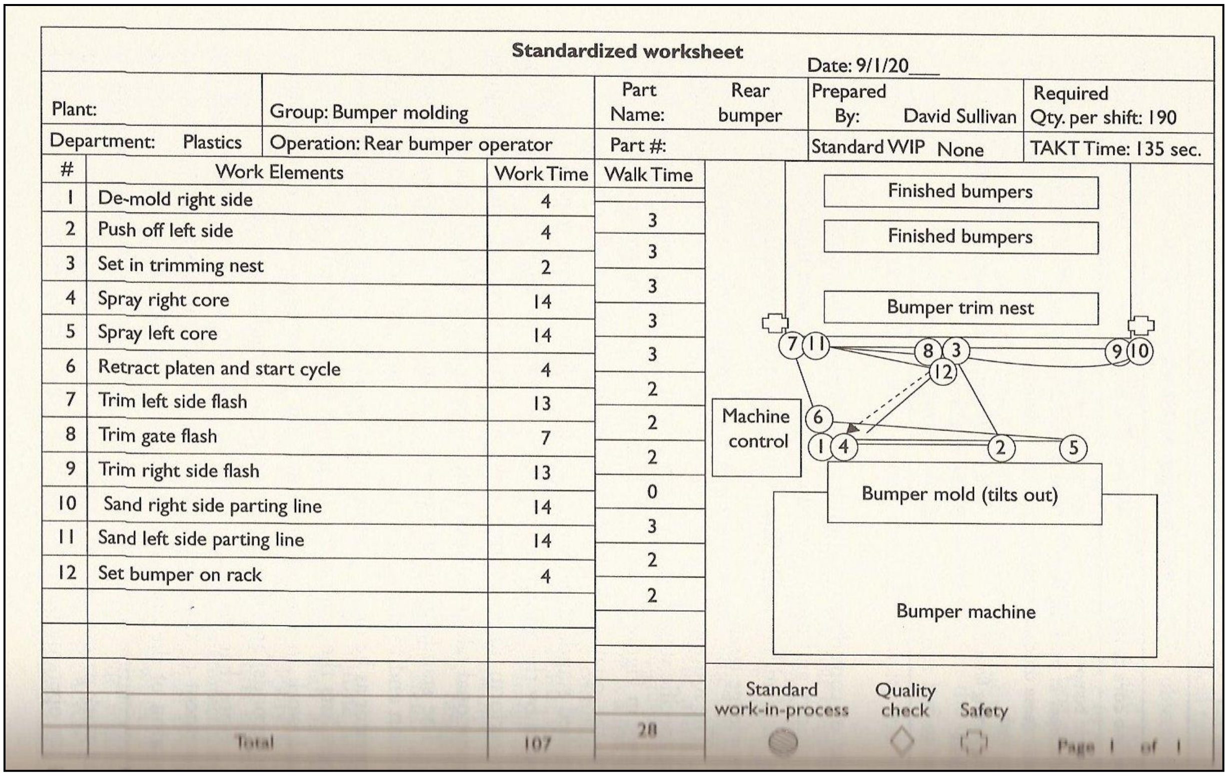
After the ideas were identified, they were reviewed and prioritized to which idea was the easiest, quickest, and best cost-effective and then implement it first. In this case, the standard work idea was selected because standard work was needed and it only required the group's effort to implement and outside approval (Lean applies standards to all practices to be able to see the waste in any process).

ii. Applying Standard Practices

Liker (2004) stated his sixth principle: standardized task are the foundation of lean process. To eliminate variation, waste, processes needed standards, and if followed properly, these standards create a repetitive nature so that any deviation to the standard acts as a signal to react or investigate why. Traditional standard work creates steps or tasks to follow for the assembly of a particular part and is very detailed about those tasks which are also very repetitive (Liker, 2007) and the task must be complete within the takt time, but in this application where the specific task vary, standard work is applied slightly different from its traditional applications.

1. Standard Work

In order to determine what the standard work is for a particular process a process is followed. A process flow map is created for an individual's task. This is the lowest level of process flow mapping. At this level the tasks are broken down into task boxes and are listed in the chronological order of how they must (or should) be completed to provide the best quality and cycle time of the task. In manufacturing, standard work looks like the example in Figure 19, which depicts the molding of a bumper (Liker, 2007, pg. 128). It depicts the time standards for each element and a takt time of 135 seconds.



Standardized worksheet Date: 9/1/20___

Plant:	Group: Bumper molding	Part Name: Rear bumper	Prepared By: David Sullivan	Required Qty. per shift: 190
Department: Plastics	Operation: Rear bumper operator	Part #:	Standard WIP None	TAKT Time: 135 sec.

#	Work Elements	Work Time	Walk Time
1	De-mold right side	4	
2	Push off left side	4	3
3	Set in trimming nest	2	3
4	Spray right core	14	3
5	Spray left core	14	3
6	Retract platen and start cycle	4	3
7	Trim left side flash	13	2
8	Trim gate flash	7	2
9	Trim right side flash	13	2
10	Sand right side parting line	14	0
11	Sand left side parting line	14	3
12	Set bumper on rack	4	2
			2
	Total	107	28

Figure 19: An Example of Standard Work at a Bumper Molding Station (Liker, 2007, p.128)

The manufacturing example of molding a bumper has twelve steps or called elements list on the left side of the diagram. On the right side the movement of the worker within the work space is shown, corresponding to the work elements. In office or transactional work, however, the standard work lists the elements of the task but there is no diagram, because it remains on the computer and/or at the worker's desk and there is no takt time. There is an estimated time to complete task but not based on a takt time to balance work. The task elements are also generic in nature because the tasks are basically up one level above the actual specific task completed like the process flow map (such as make design changes element verses actual task such as changing ProE drawing file parts and dimensions and adding filets or radii).

The process boxes were translated directly to become the elements listed in the standard work. If the work is critical or complex, the elements will describe more detailed than the process boxes did to assist the worker. For example, in a creating a layout drawing for a wood piece, the designer must determine the individual piece sizes to be cut from a larger board. Not only the dimensions and the layout must be determined, but also space between the pieces for allowance for the cutting tool path and depending upon the specific product ordered, the designer may also need to add extra material for a secondary cut such as edge-banding cuts. Element 12 on the designer's standard work says 'reference cutting clearances' which is stated to have the designer check the cutting clearances for not only the first cut but a possible second as well by utilizing a look-up table (matrix) for the specific details. This call out is critical to avoid scrapping parts, waste.

In processes which have multiple paths, different standards are written for each path. For example during the designing process, if the custom product request is a simple design, the simple standard work is used; if complex, the complex standard work, all based on the complexity, which also varies the time.

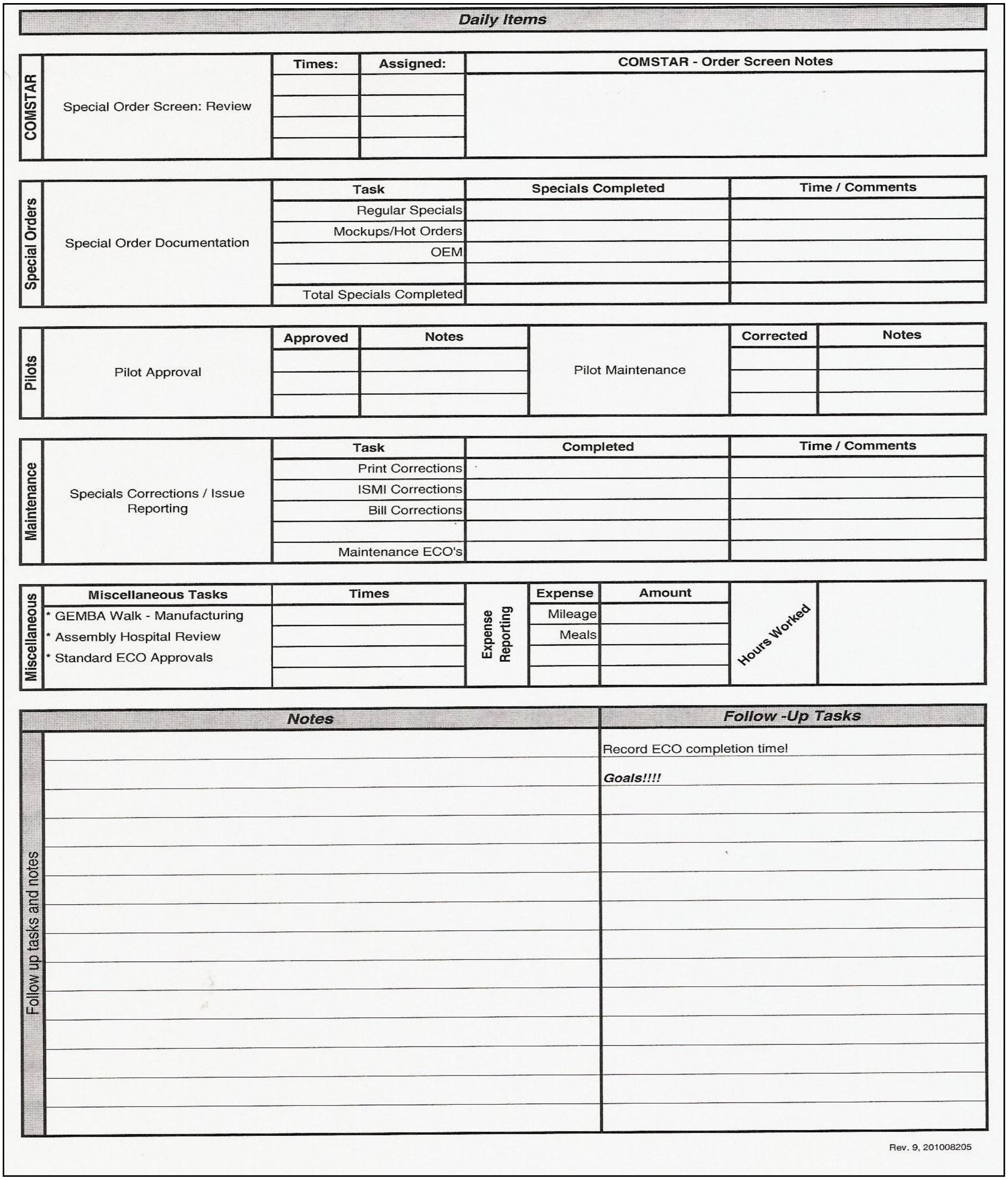
The standards create accountability for each department member. It creates a standard way to complete their work for quality and time measurements (time based on historical data). The Figure 20 shows the standard work for a simple design where its time allotted for completion is 45 minutes.

Standard work			Prepared by:		
WC#: Step 2	Product Family: Wood		Date:		
WC Name: Designer -	Complexity: Simple		Cycle time: 45 minutes		

#	Work Elements	Time Work(S)	(F)	wait
1	Go to Comstar look up next order			
2	Open order			
3	Pull any reference info from folder			
4	Print info			
5	highlight required info : standard part and inquiry #			
6	open new SPECO			
7	open OLP			
8	check custom matrix for similar part			
9	open AMAPS pull BOM from Standard Part			
10	Open ProE - CAD - get drawings of standard products or similar part from matrix per part numbers			
11	open PDM link to store and save work			
12	Create new product - reference cutting clearances			
13	Update parts names and numbers			
14	update drawings with new numbers and quantities			
15	and export file			
16	Export to OLP			
17	Export to ISMI			
18	Print info			
19	validate sizes - ISMI			
20	complete SPECO			
21	validate BOM item quantities			
20	Reocrd time and complexity on daily task sheet			
22	Sign and submit			
	Total			

Figure 20: Standard Work of the Designer's Tasks

Besides the multiple standard works per complexity per order, there are other task assigned standard work that an individual must be utilized daily. Figure 20 was the task of designing the product by the designer, but the designer must also follow their daily task standard work. The designer's standard work is a layer higher and includes the standard work creating an order. The designer's daily standard work is shown in Figure 21.



Daily Items

COMSTAR		Times:	Assigned:	COMSTAR - Order Screen Notes
	Special Order Screen: Review			

Special Orders		Task	Specials Completed	Time / Comments
	Special Order Documentation	Regular Specials		
		Mockups/Hot Orders		
		OEM		
		Total Specials Completed		

Pilots		Approved	Notes		Corrected	Notes
	Pilot Approval			Pilot Maintenance		

Maintenance		Task	Completed	Time / Comments
	Specials Corrections / Issue Reporting	Print Corrections		
		ISMI Corrections		
		Bill Corrections		
		Maintenance ECO's		

Miscellaneous	Miscellaneous Tasks	Times	Expense Reporting	Expense	Amount	Hours Worked	
	* GEMBA Walk - Manufacturing			Mileage			
	* Assembly Hospital Review			Meals			
	* Standard ECO Approvals						

Follow up tasks and notes	Notes	Follow -Up Tasks
		Record ECO completion time!
		Goals!!!!

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Figure 21: Example of the Designer's Overall Daily Standard Work

The daily standard work sheet is to be completed and turned in daily to the design manager. Everyone in the department as well as the design manager, all the way up to the plant manager, should have their own standard work – this is part of the lean methodology of "standardized task as a foundation" – creating standards for all (Liker, 2004).

Standard work is the enabler to create a baseline or stability measure. It enabled the designer manager to be able to track the performance or productivity of the designers (shown in Appendix L) and designer in need of training especially when training to a new process.

2. Job Breakdown Structure

Another lean tool used injunction with the kaizen on the designer's standard work was to create a job breakdown sheet (JBS) of the designers' standard work. A JBS is a behavioral learning tool. It was used to help the designers become acclimated to the new method in which they must perform their designing task. (JBS details are discussed in Appendix M). A generalized JBS is shown in Figure 22 in which element 12 of the standard work, the wood size calculation, is pulled out of context from the rest the standard work to illustrate the point. The critical emphasis of the JBS is the keypoints which references details: "How to do," the calculations and "Why it is done," affected quality if not completed.

Job Breakdown Instruction	BPU #	Prepared by:
WC#: Step 2	Part Family: Table	Part #:
WC Name: Designer	Part Name:	Operation #:
Approvals:	Mfg Eng:	Quality:
Work Element ***(WHAT to do)***	***Detailed Instruction*** ***(HOW to do it)***	***Key Learnings*** ***(WHY you do it that way)***
1.calculate table dimensions for wood layout	1. The table has wood has what edgeing? l - wood edgeband add 10 mm - plastic edgeband - 0 mm - cascade edge - 15 mm - laminate top - add 5 mm - veneer top add 0mm	1. The different edges require second cuts to cut the side of the wood to match the mounting method of the edgeband. If not added , when cut will remove material and table will be too small
2. Run ISMI for	2. Run macro to create cutting path to create wood layout .	2. the proper size board is used so scrap does occur

Figure 22: An Example of a Job Breakdown Sheet of the Wood Calculation

Gielingh (2008), Ruy (2008), and Cooper (2008) all agree that the process of learning encompasses more than just the memorization of a list of tasks. Learning is a cognitive process, and reasons for why things have to done in certain ways helps to teach; therefore, the JBS tool helps with the cognitive learning process thusly the new standard was quickly learned and accepted.

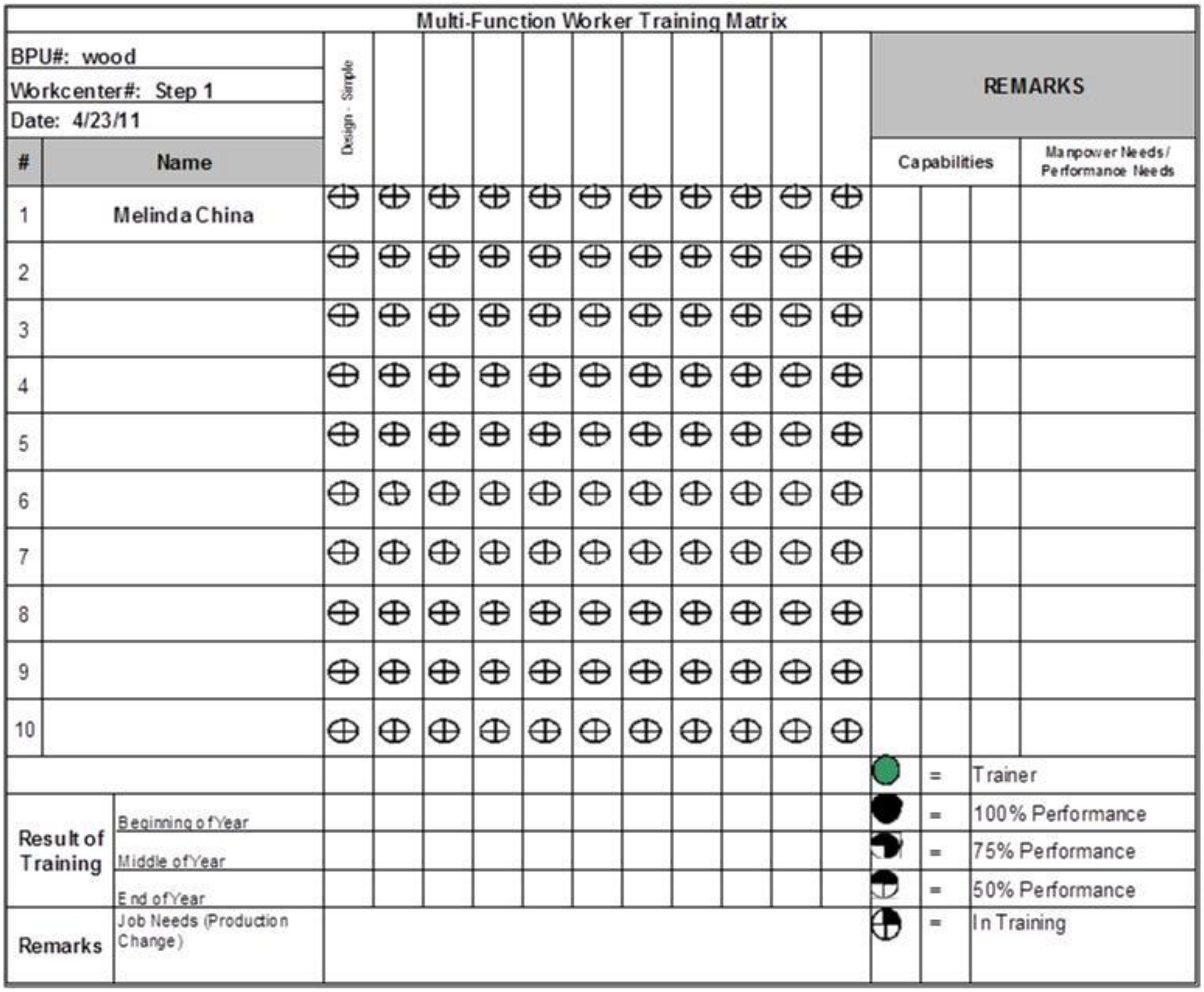
(For example, when teaching a child not to touch an iron, the parent will say not to do so because the iron is hot. After the child understands what “hot” means and that “hot” hurts, he or she will not touch hot things in the future. The same is true with JBS. When the workers understand “why” they have to the calculation and “what” errors it eliminates, they will be more inclined to follow the instructions than without the "why." Designer will find out the "why," but the hard way—through creating issues.)

By implementing the designer's JBS, it also ensured that the change made in the process were thoroughly understood and followed by the designers by measuring their productivity and check sheets accuracy. After all the designers become proficient at the standard work, it then becomes the new best method or baseline (standard), but not until. When the new standard work becomes the standard of the task, is when the kaizen is almost complete. The last step is document the proficiency of following the new standard work.

3. Training Matrix

There is a JBS for each standard work and all JBS/ standard works should have a correlating training matrix to document the proficiency or the training level of the said standard work. A training matrix was created for the designers and on the designer's training matrix, for the standard work for a simple design; it initially had the designers documented as "in training." Over time as the designers became proficient at that JBS, the status of his/her performance changed corresponding to his/her performance level at that standard work. The more proficient the individual gets at doing the standard work, his or her level on the training matrix changes, as represented by the four quadrant circle changes to the appropriate circle (Liker, 2007).

An example of a training matrix is shown in Figure 23 where the columns at the top of the matrix, list the different on JBS (standard work), and the workers, or department members who participate in the training, names are in the rows on the left. As workers receive training, the four quadrant circles are used and the quadrant circle legend is on the bottom right of the matrix.



Multi-Function Worker Training Matrix

BPU#: wood
Workcenter#: Step 1
Date: 4/23/11

#	Name	Design - Simple											Capabilities			Manpower Needs / Performance Needs
1	Melinda China	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
2		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
3		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
4		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
5		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
6		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
7		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
8		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
9		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
10		⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕	⊕				
Result of Training	Beginning of Year															
	Middle of Year															
	End of Year															
Remarks	Job Needs (Production Change)															

REMARKS

= Trainer
= 100% Performance
= 75% Performance
= 50% Performance
= In Training

Figure 23: An Example of a Designer Training Matrix

From the training matrix, the assigned skill level of the designers can be used to assign the appropriate complexity of custom products to the appropriate skilled designers. By assigning designers the appropriate product complexities per their skill and knowledge, it will help to eliminate errors and increase throughput --time and accuracy through step 2 in process II.

With the training matrix completed, the kaizen has been completed. The measurements in the process will show if the kaizen was effective long term and or if more improvement or changes are needed to the standard work. Then next and last step in the lean application process was creating the environment of continuous improvement.

j. Continuous Improvement

With the completion of the kaizen on implementing the designer's standard work, its JBS and its correlating training matrix, it was time to move to the next kaizen on the priority list. The continual implementations of kaizens are called *Continuous Improvement.* Continuous improvement means that change is always occurring and never ends because of the perpetual pursuit of the ideal future-state. Detail information on the Continuous Improvement cyclic can be found in Appendix F. Embedded in the continuous improvement cyclic is also a loop for specifically improving the standard work process; improve, stabilized, new idea, improve, stabilize, etc.. The loop is shown in Figure 24.

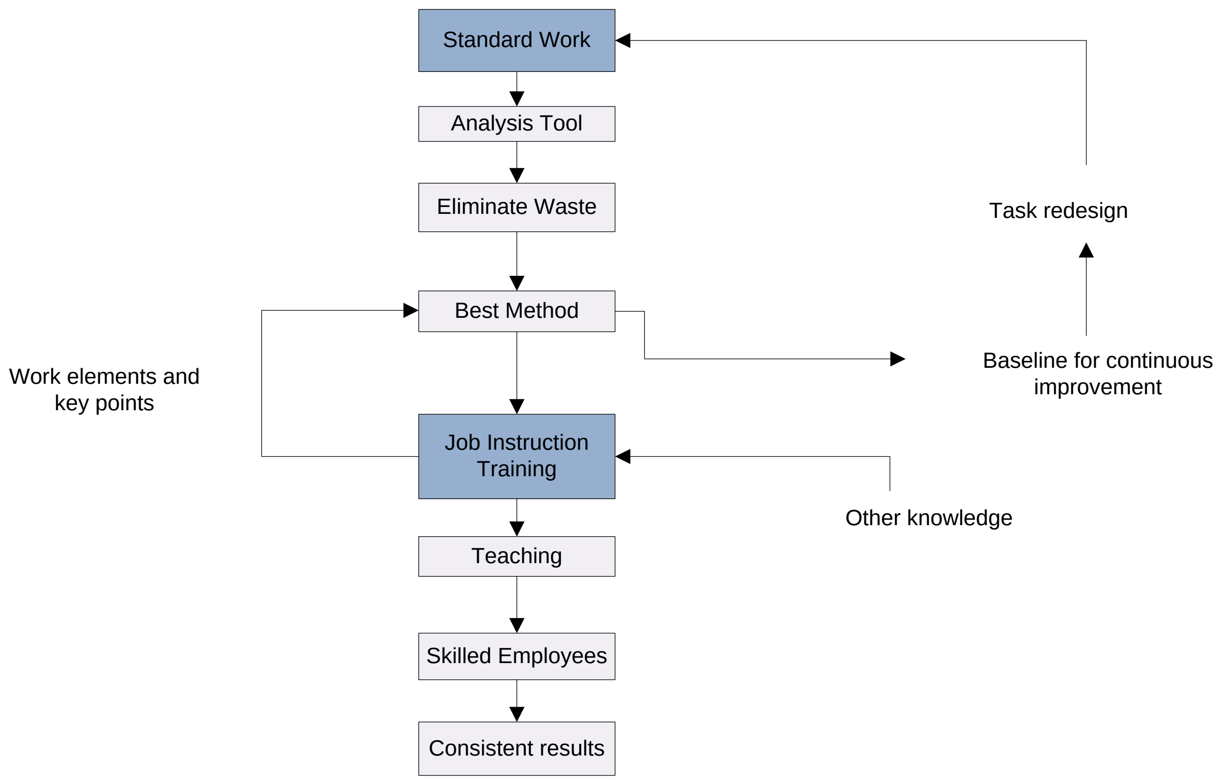


Figure 24: The Correction Action Loop to Improve
Standard Work with JBS (Liker, 2007, p.118)

The corrective action loop was followed completing the kaizen on the BOM error elimination and on three other kaizens following the methodology: analysis, brainstorm, standard work, JBS, measure, training matrix, and implementation. The four kaizen were only the beginning of the lean journey on the custom development process, but the process was improved.

VI. Results

There were four kaizens that were completed implemented throughout this study but there were over eighteen ideas identified. These ideas are listed in Table II.

Table II: List of Improvement Ideas

Process	Step	Issue	Ideas
I	overall	measurement	Create check method for RFQ
I	3	customer error	create Drawing for customer to review and approve
I	3	complexity	create distinct definitions for complexity and lead time to complete
I	3	measurement	create measurements for cost and lead time quotes versus actual
II	3	measurement	Improve the check sheet for both accuracy and time by creating standard work by complexity level
II	4	measurement	Create a method to check the time and accuracy of the BOM technician by creating standard work
II	5	measurement	Create a method to check the time and accuracy of the Routing technician by creating standard work
II	overall	BOM errors	Create Macro in ECO to count items to verify against Drawing items
I&II	overall	measurement	Change the first pass yield to reflect the true measurements and change equation and nomenclature to reflect the changes
I&II	6	scrap	Drawing is submitted as part of Pilot to make sure part matches drawing
II	overall	measurement	add any correction or rework completed into the database include where found and error type
I&II	overall	accountability	new performance goals
I&II	overall	Training	Create Training - matrix
I&II	overall	JBS	Usage of Job Breakdown Structures
II	6	pilot	review the routing time actuals versus the quote and what was entered into system… create database to track time for better estimates for quotes
I	2	customer error	increase feasible products
I&II	overall	Standards	Create standard work for all involved - management too
I&II	overall	kaizens	Create teams to work on Kaizens

The list includes the ideas that were identified to improve the process to initially start being lean including the rationalization of the FPY metric as well its corresponding process flow step in the VSM. As mentioned, four ideas were implemented including the detail implementation of standard work, JBS and its corresponding training matrix.

Another idea implemented that is the second one listed, was the creation of an AutoCAD drawing of the custom product(s) requested in Process I. It was found that even though the RFQ required a drawing or sketch to be submitted through a required field in the RFQ (system error proofed not allowing the RFQ to be submitted into the system), customers would circumvent the system and not include a sketch or drawing, but include a jpeg of something else. While witnessing the inquiry technician doing their job, a RFQ was submitted with an attachment of a smiley face instead to fulfill the drawing requirement. The idea was to create the drawing to eliminate the guess work of what the customer was possibly trying to convey in his or her request, by creating a visualize concept. The idea was implemented and now an AutoCAD drawing as shown in Figure 25 is created and is reviewed and approved by the customer as part of the RFQ process. The drawing has eliminated conceptual idea confusions and has eliminated waste due waiting on clarification or questions on the design. To expand it, the concept to eliminate non- feasible products by suggestion an alternate design with capability is in the works. The drawing approval process it still has more work to make the approval process become contractual, but it is in process as well.

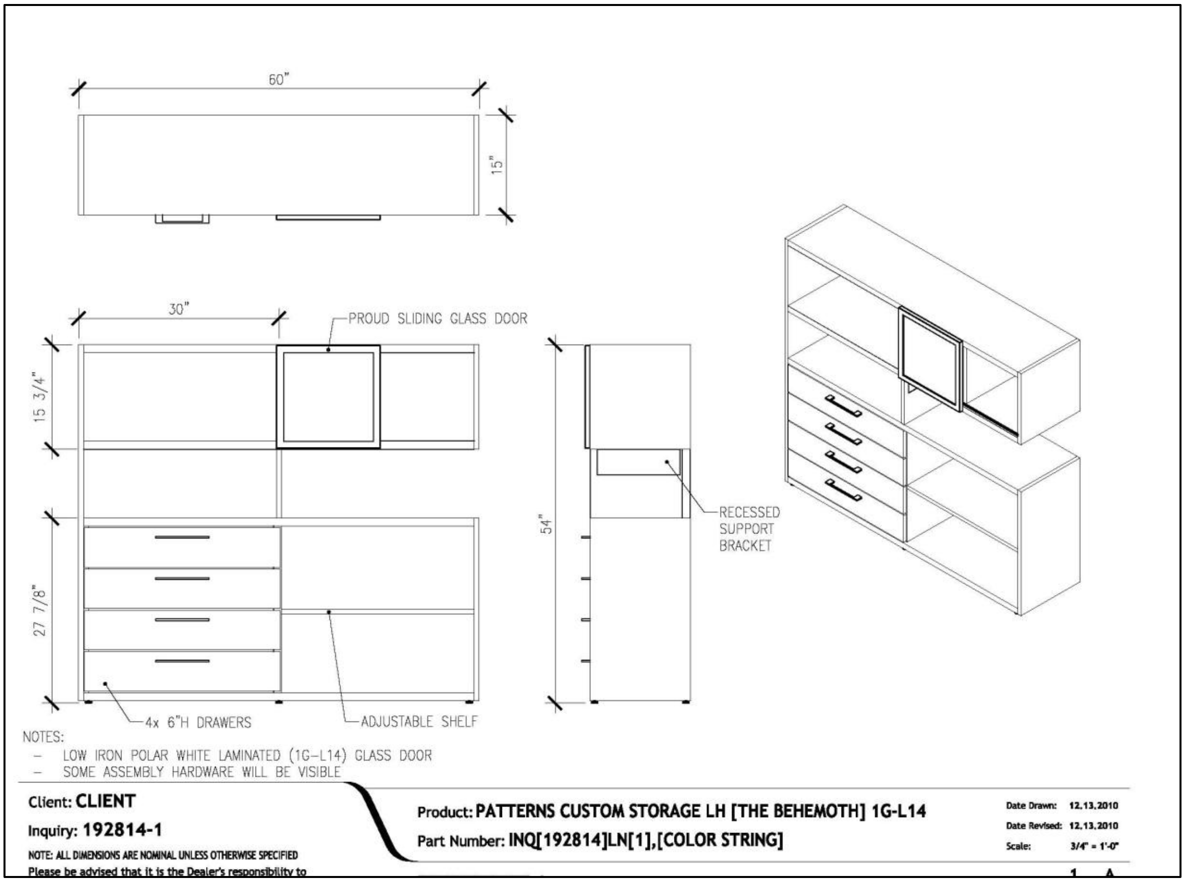


Figure 25: AutoCAD Drawing of Customer's Request
for Quote to be Reviewed and Approved (Another example in Appendix N).

Another implemented idea within the RFQ process was the collection and analysis of inquiry technician's tasks. The time and accuracy of Process I was recreated and called the Request for Quote First Pass Yield (RFQ FPY). Figure 26 shows the results of the error types in a Pareto format from the RFQ FPY. The technicians are now provided with their largest problem, design details, in which to brainstorm ideas to have a kaizen to eliminate or reduce.

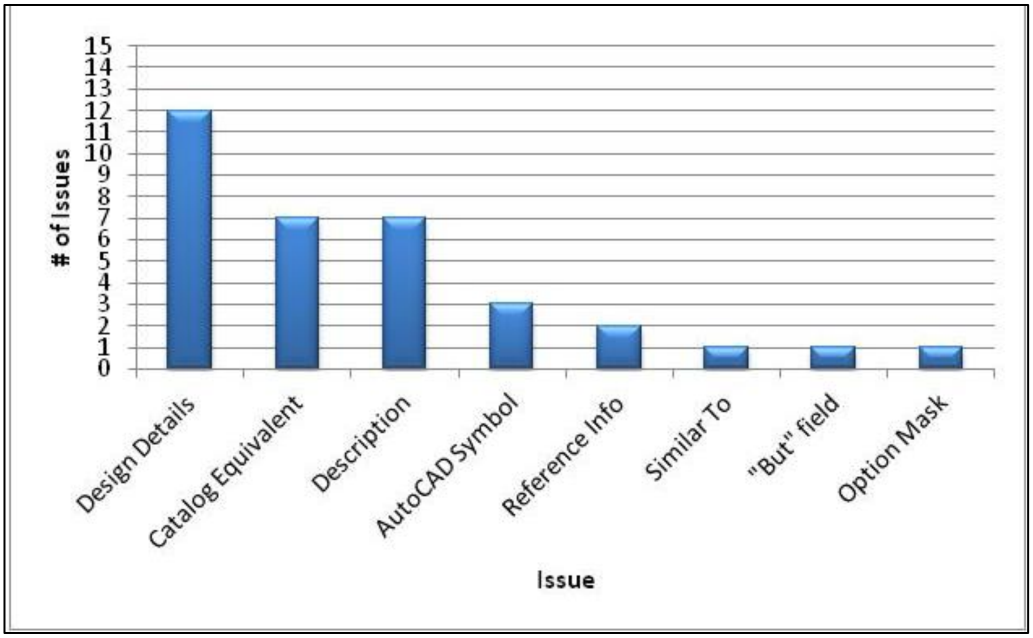


Figure 26: Pareto of the error types created by Request for Quote FPY process.

The third kaizen implemented, was to improve the pilot review audit. The idea was to take the drawings of the product requested and create a finish three-dimensional drawing to compare to the finished part(s) during the audit to ensure they matched. The finished drawing created a visual check methodology. The issues that were caught were issues such as wrong designs including missed holes or cutouts, ort hem placed them in the wrong location or wrong handed designs because the design somehow got flipped.

The fourth kaizen as part of the study occurred In April 2011. The designers check sheet (ECO checking) process was changed. The results of the accuracy are shown in Figure 27, which shows that the check sheet errors declined was in place, but there was an increase from June to July which can be attributed to a special cause. (Appendix O) that was later identified as problem to be fix.

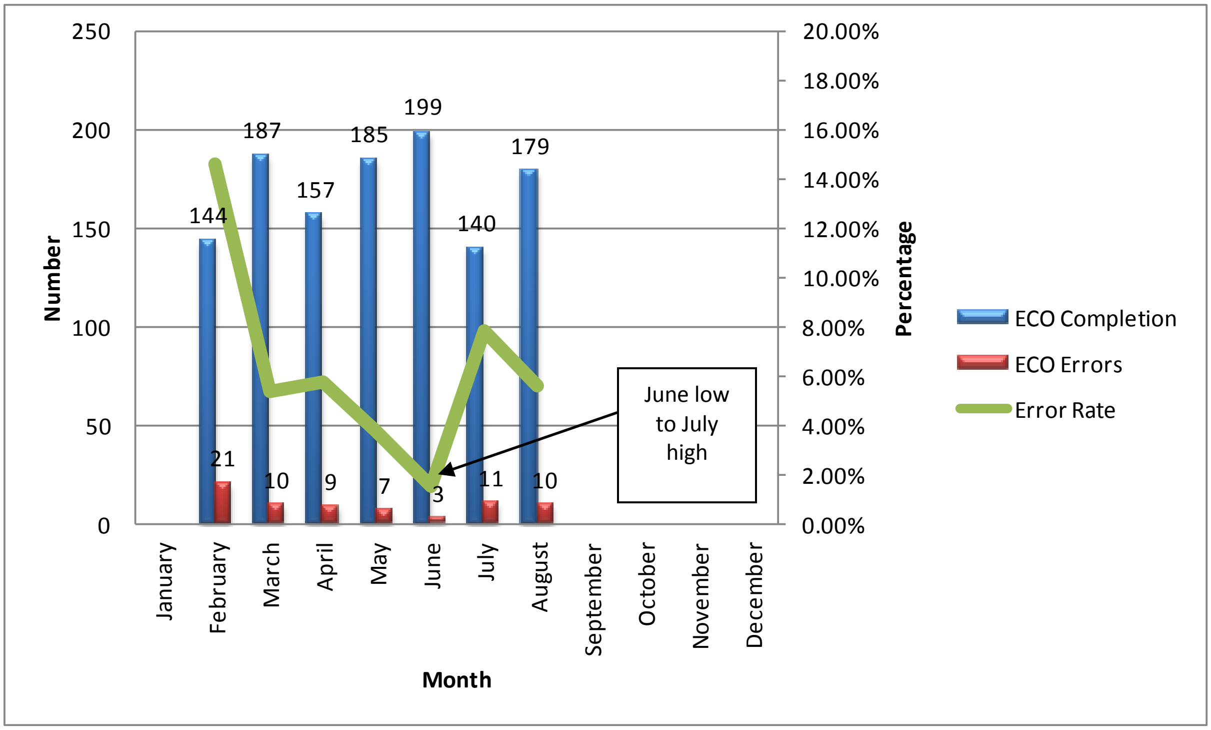


Figure 27: ECO Check Sheet Error and Error Rate per Month

From the outcome of the improved designer check sheet, the design manager has also able to calculate the Designers' capacity, (how much work a designer can complete in a given day) (shown in Table III) and designer productivity (Productivity meaning the ratio of what was completed to what was required) as shown in Figure 28.

Table III: The design capacity per designer

	Capacity			
Designer	1	2	3	4
2011 YTD	0.32	0.17	0.18	0.17
April	0.37		0.19	0.18
May	0.27		0.09	0.20
June	0.50	0.15	0.24	0.17
July	0.16	0.19	0.20	0.21
August	0.31	0.17	0.19	0.08

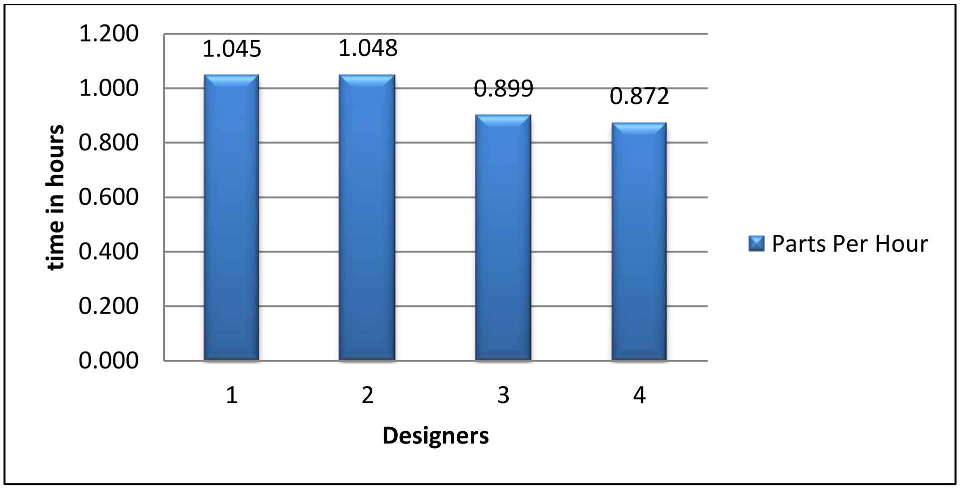


Figure 28: The Productivity of the Designers Measured by Parts per Hour

The cost of quality (COQ) of the custom products was tracked and was found to be improving over time as shown Table IV.

Table IV: Cost of Quality

	2012	2011	2010
January	$ 57,000.00	$ 87,000.00	$ 49,000.00
February	$ 63,000.00	$ 72,000.00	$ 100,000.00
March		$ 135,000.00	$ 150,000.00
April		$ 86,000.00	$ 71,000.00
May		$ 60,000.00	$ 93,000.00
June		$ 127,000.00	$ 211,000.00
July		$ 134,000.00	$ 120,000.00
August		$ 144,000.00	$ 146,000.00
September		$ 110,000.00	$ 257,000.00
October		$ 70,000.00	$ 147,000.00
November		$ 84,000.00	$ 603,000.00
December		$ 243,000.00	$ 228,000.00
totals		1,352,000.00	2,175,000.00

The graph shows that since the initial investigation through the implementation of a few lean tools, the cost of quality in terms of FPR dollars and its frequency over time has been reduced from 0.9 to 0.25 millions of dollars (rolling month). The FPR quality measurement was dropped because the data was not able to accurate reflect true quality levels and new quality measurement will be the new "true" FPY measurement, determined from equation [1].

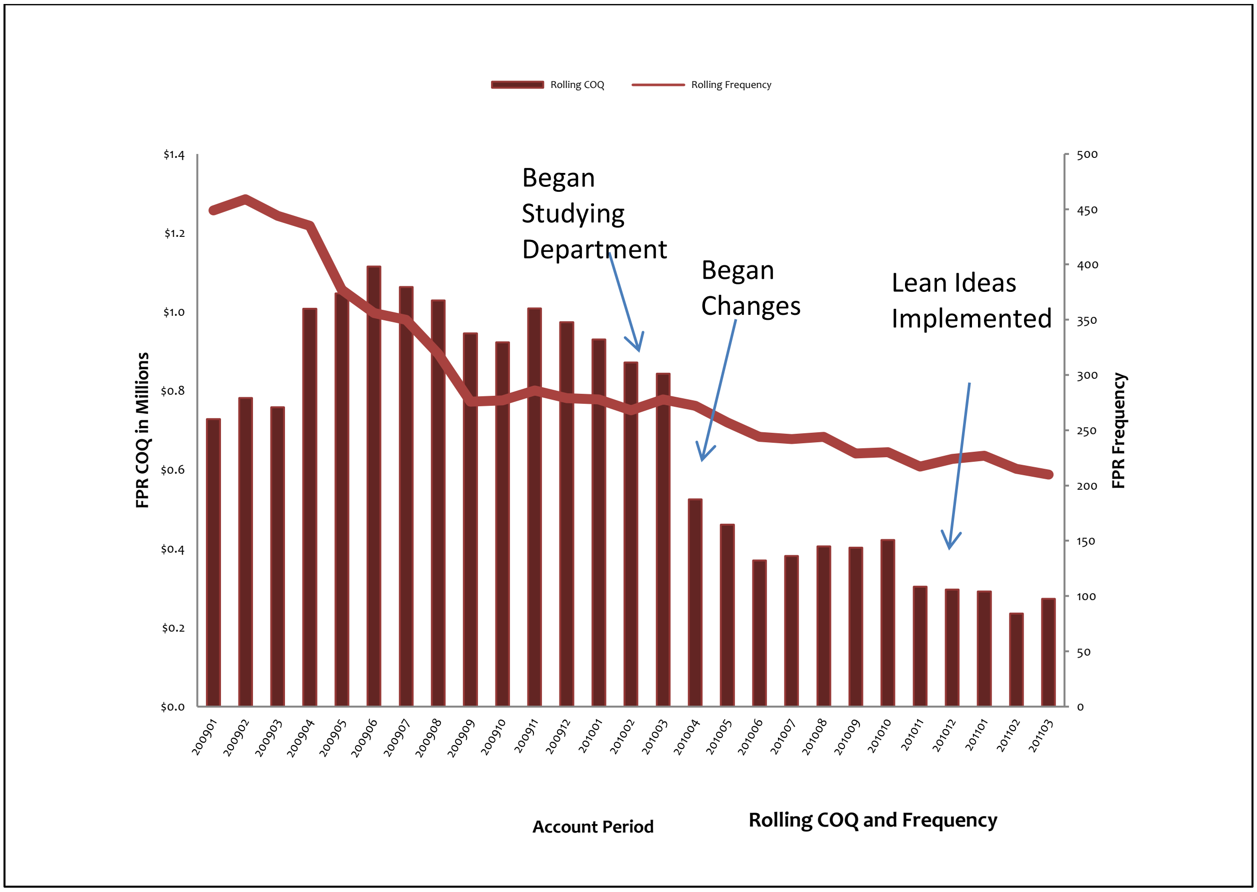


Figure 29: Cost of Quality (COQ) of the Custom Products in Rolling 12-Month Calculation Increments from January of 2009 until March of 2011 (The "x" axis is designated by number that represents the year month first as the first four digits and the month the last two.

The FPY performance was continually tracked even after the initially study and the implementation of the four kaizens. Figure 30 shows the FYP performance through September 2011 and Figure 31, the first four months of 2012. The data indicates the quality performance has remained stable (note the scale).

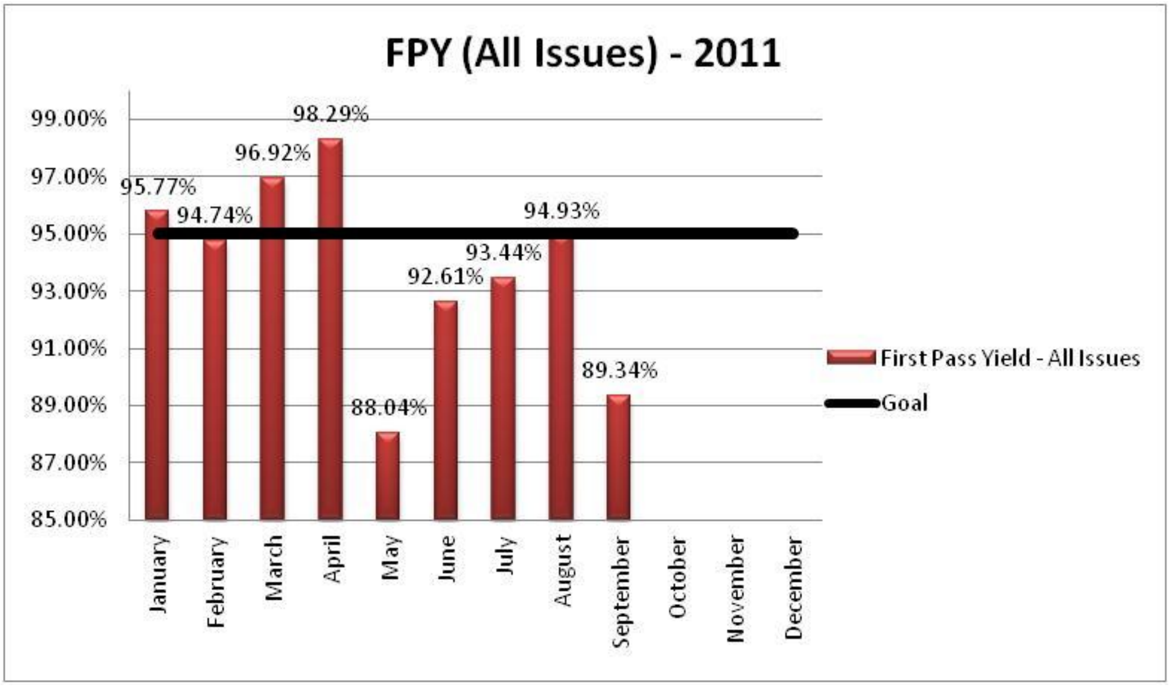


Figure 30: FPY Data from January to September 2011

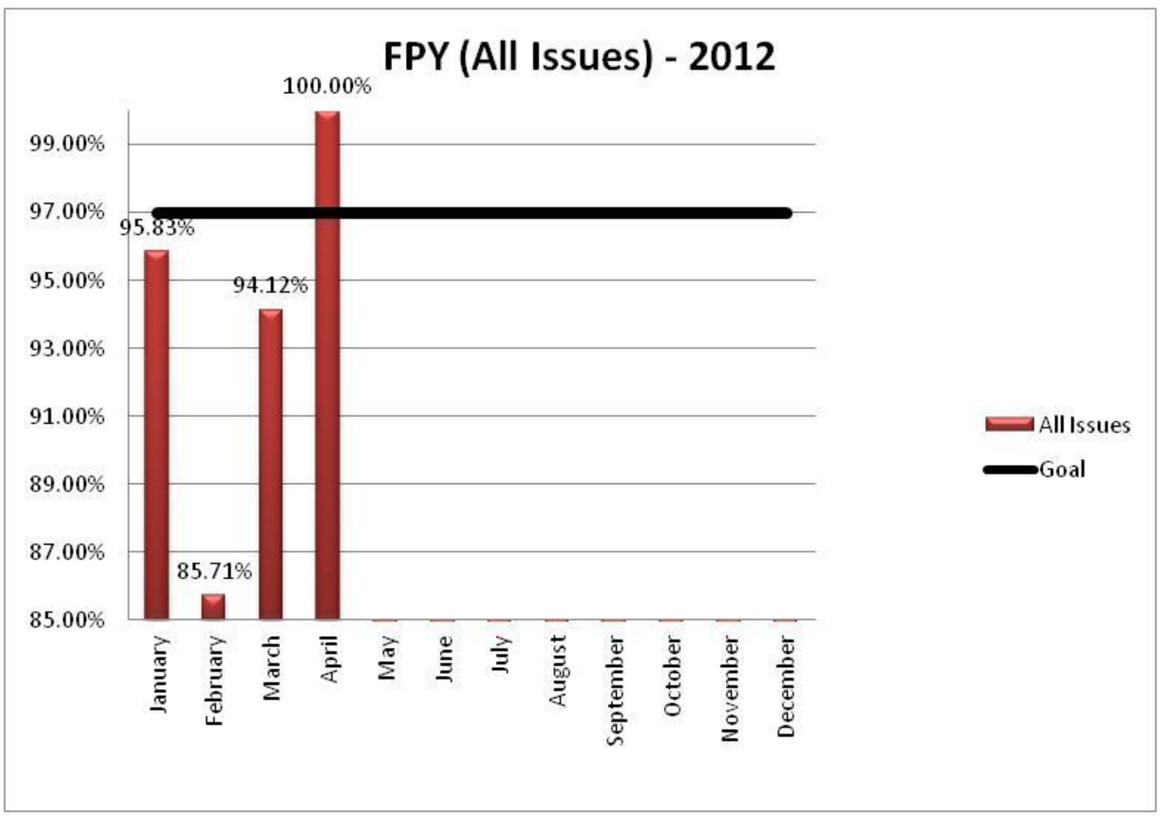


Figure 31: FPY Data from January 2012 to April 2012

VII. Discussion

Lean can be applied to any process including custom product development processes, even they vary in every aspect: their process, complexity, designs, design and manufacturing time, quantities, and cost, they can be quantified to be measured and then improved. Applying lean to custom process differs slightly from traditional methods, high-volume low-part mix manufacturing in terms of how things are standardized and measured, but the overall goals remains the same: to eliminate waste.

Danford (2011) attempted to put traditional lean tools and methodology to use in a job shop. He had to abandon these endeavors, to think beyond traditional lean methods to standardize the process. Just like the Danford's job shop, the custom product development process had to look for alternate methods for standardization. In high-volume low-mix applications traditional lean works well, but in a high-mix low-volume process traditional lean setups and takt time cannot support the all the possible variation of different edges, sizes, or surface finishes for examples that a customer could request because their times vary considerably and there is not predictability of what might be ordered next and or when. What did work in the custom job shop was to follow hybrid work cells or processes where standardization was not product attribute specific but flexible per the needs of the product requested.

From the definition, a custom product has attributes of the standard product it is based off of, but with variations. These variations may require not only the design details to change but the manufacturing processes as well. For example, a standard three by five feet table with four steel legs at the four outer edges is requested to be that standard three by five feet table but requested specific hole cut outs for cables. The process would follow the process outlined for the designer for a simple order in Appendix M in which the design would include a change in the table top and an extra part, a bezel for the hole. The routing of the product will require extra manufacturing process steps, off line the drilling of the hole (removed from the standard process and then but back) and attachment of the bezel during assembly. These extra steps would be hybrid steps that would add time and cost to the product that would disrupt normal takt time of a high-volume product, but is adapted in the ERP system the first time it made using hybrid cells areas utilized by custom products.

These hybrid process become hybrid methodologies that become necessary to implement lean in custom product development process though the traditional lean tools and approach can be used. The six steps to follow are the following:

1. Capture and create a current process flow map,
2. Capture and create balanced metrics
3. Identify the waste or non-value steps,
4. Create future state process flow without the waste,
5. Identify projects to bridge gap,
6. Continuous improvement or corrective feedback loop.

Rother & Shook (1998), Liker (2004, 2007), Womack (1996), Locher (2008), and Oppenheim (2004) have discussed variations of these steps, varying numbers of steps and or details, but the emphasis in all cases remains the same, to eliminate waste by understanding the value of each step in the process. In the custom process, the meaning of value is not necessarily 100% the same as the traditional lean thinking of "what the customer will pay for" but rather the value of producing products as efficiently and effectively as possible, yet still pay for since custom products meet a different market requirements and demands.

The following the process, the first step in creating a lean process is to document the process at the high level, 5000 foot level. The documenting includes process steps that are being followed and which are not and if there are any workarounds. Even if there is already a documented process, it will need to be validated to show that it is the actual process being followed and not just a process documented on paper.

The second step will be to document the metrics and goals of the process. How is the process measured for time and accuracy recalling that the process boxes outputs should be the required inputs for the next process, and so-on. The process flow and the metrics are combined to create the current-state VSM. The VSM will provide a visual of the overall flow and measurements of the process. Recall a review of how to create VSM may be helpful in order to be able to complete one, and is referenced in Appendix B.

The VSM needs further and more examination to ensure that the process has the correct measurements being captured, measuring what is important to the customers—internal and external customers as well moving upstream in the process to ensure that they correlate. The validation was done with the investigation or tracking of the 21 orders which determined that the 95% First pass yield being reported was not in fact an first pass yield result. The data was instead just the results of the pilot review audit, the review conducted after manufacturing, because corrections were being made throughout the process inflating the FPY results. When the proper calculation of FPY was done, equation [1], from the twenty-one orders, the results were staggeringly lower at 7.7% versus the 95% previously overstated of the overall results of same period (January through March).

The third step in the process is to identify the waste or what does not at value in the process. Waste may be any of the eight commonly known wastes: overproduction, waiting, transportation, processing, defects (scrap and rework), motion, inventory, and under-utilization of resources. Defects were the largest waste in the furniture example, in which a large amount defects were hidden in rework or correction being done, as shown in the disparity between the

7.7% FPY true measurement versus the 95% initially claimed. The members/workers may not realize that doing a correction is rework until it was pointed out to them. Rework is a hidden factory and often it is not realized.

There were three clearly identified wastes in the custom product development's process and these waste needed to be eliminated. Brainstorming, a lean tool, was used to identify ideas to eliminate waste in the process also gives the department/team/workers an idea what the ideal process should be without waste. This ideal process state is called the future state. The development of a future-state VSM is the fourth step in the process. The future-state VSM should include any new goals and metrics that were identified to measure the time and accuracy of the process and they should correlate to customer and business goals and measurements. The brainstorming ideas generated show

The fifth step in the process is to bridge the gaps between the future-state VSM and the current-state VSM. Ideas to bridge the gaps, such as the projects to eliminate waste, are identified and placed on the current state VSM as kaizen bursts clouds. The kaizen bursts clouds are an icon that is placed on the VSM in which its location identifies where the gap is and within the icon is the idea that needs to be implemented (how to complete kaizens are referenced in Appendix P). The ideas are then prioritized as to which need to be completed first based on highest impact and control to be completed. Impact refers to the cost, timing, and ease in implementing, and control signifies that the team has the power to make decisions to change the event or process without having to get outside approval. The idea with the highest priority is implemented first and so-on.

Kaizen events are an important part of applying lean. During kaizens, lean tools are shared, taught and used. Depending on the problem and makeup of the team, different tools can be used. In the custom product development process, data analysis was conducted first, using pareto graphs, but pie charts or histograms or other analysis tools can used and the tool the team is most familiar with should be used. After data analysis is completed and problems are identified, their root cause needs to be identified to eliminate (quality tools are embedded within lean). To find the root cause(s) tools such as "fishbone diagram" or called a cause-and-effect diagram "or five whys can be used (A reference how to complete a fishbone found in Appendix K).

In the furniture example, a fishbone diagram was used to determine the root causes of the wrong quantities error type of BOM errors was used to illustrate how to use data analysis to then solve for root cause to then identify potential solutions such as the implementation of Standard work. Standard work was just one of three ideas listed to eliminate wrong part quantities, but it was the easiest and also provided a means in order to introduce it. Also when standard work is implemented, not everyone has the same skill set; therefore, training will be required to get everyone to the same level. Lean values training as a very important factor to not only embrace the users to learn the new skill, but to cognitively learn the new skill by using another lean tool called the job breakdown sheet (reference Appendix Q). JBS is a tool that not only helps with the steps and process but helps with the behavioral learning as well. Behavioral learning has been proven by Ruy (2008), Cooper (2008), Liker (2008), and Chapman and Hyland (2004) to help individuals learn faster and get improved performance more quickly, a feature (or advantage) made possible by the three columns in the JBS.

Once the team/department/workers are trained, their training is documented by the use of a training matrix. It is used to track the performance levels of the individuals and identified the needs of individual, (elimination of the eighth waste) and helps them meet the team goals.

Examples of the tools used in one complete kaizen: data analysis, fishbone, standard work, JBS, and the training matrix was shown in its entirety from start to end, to show how all the tools relate to one another and in the end how measuring the result of the change is the last step of the kaizen or data analysis is occurring again. This is the last step of applying lean, the continuous improvement cycle (Appendix Q).

After one kaizen has been implemented and measured for effectiveness, then next kaizen should occur and then the next. In the study the custom product development process, four kaizens were implemented in this manner and its quality improved over time as was shown by the reduced cost of quality dollars shown in Table IV. The process is still at its infancy of the lean journey but if the furniture continues to conduct kaizens, they will improve (step 6) and will continue to become more lean. With the completed work shown, other companies can use the methodology and tools that were applied to the custom product development process at the furniture company to their process and become lean as well.

VIII. Conclusion

The custom product development process at $1.3 million in sales office Furniture Company began down its lean journey January of 2010 and by May of 2011 had made strides in becoming lean reducing its cost of quality and improving its internal quality performance as follows:

- Future-State VSM which identifies future goals and process
- The FPR frequency reduced from 450 to 200 per month
- FPR cost of quality reduction from $0.9 million when the study began to $0.3 million at the conclusion of the study
- Eighteen project ideas were identified during the study period Table II, page 66
- Four kaizen events completed - illustrated how to involve both people and process to effectively produce change
    1. BOM – part quantities
        - Standard work for Designers
        - JBS
        - Training Matrix
    2. AutoCad drawings
        - RFQ
        - Pilot Review
    3. Check Sheets - RFQ, Inquiry , Process I
    4. Check sheet – Designers
- New First Pass Yield metric identified Equation [1], page 41 that created measures for both time (Lead time) and accuracy (Quality) for each process step

that reflected the elimination of inflated quality (from 95% to 7.7%) and better lead time predictor

- Introduced the continuous Improvement Cycle embedded in the change process

Applications of Lean methods and tools applied to custom products and or research and development were basically not existent in published works because of their inherent variability of the product designs. This made it difficult for industries that have custom products and or Research and Development processes to apply lean principles and tools that do not follow traditional lean practices. This works provides industries with an example were Lean principles and tools were applied to custom product development process. The methodology used, the traditional steps mixed with the non-traditional, in the example can be applied to any custom product development process at any company. As Danford (2010) said, one size does not fit all; applications have to be altered to compliment the complexity of the tasks to be complete.

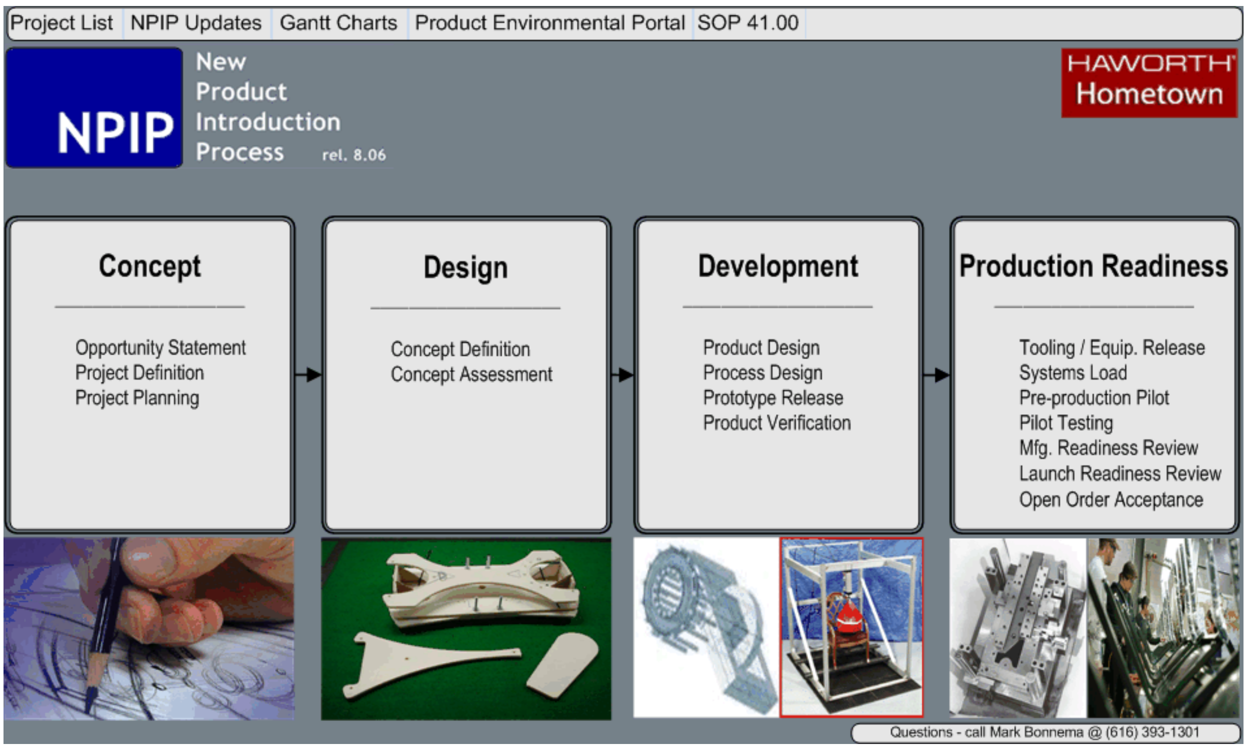
XI. Future Work

The next steps in the process are to that the measurements methodologies would be completed on the BOM and Routing processes steps to complete the FPY equation [1], along with the other ideas list in Table II. Each improvement idea in one area of the process should also be applied as applicable in the other areas of the process such as the checksheets and the AutoCad drawings were applied in more than one area. Standard work on the other design complexities levels as described in Appendix J. By completing all the levels, a more accurate productivity calculation could be created for each designer based on complexity. The productivity measurement would then enable better level loading and lead time prediction which is important customer requirement.

Further work should also be done on expanding the measurements and the accuracy of the lead time based on quoted lead times. Based on acquired new information found, the study of *Quick Response Manufacturing: A Companywide Approach to Reducing Lead Times* concepts by Rajan Suri and *Made-to-Order: Excelling in High-Mix, Low-Volume Environments* by Greg Lane that focus on improving the lead time and high-mix, low-volume applications, respectfully, would be researched. The ideas presented could compliment the given improvements presented in this work and help improve the process even more.

Appendix A

New Product Development Planning



New Product Development Process called New Product Introduction Process at Haworth

Appendix B

Value Stream Mapping

A value stream map is a tool that provides a systematic approach to document and direct a lean transformation from a system or a big picture, perspective by visually displaying the process by which work is done. A VSM is designed to capture the way work is organized and progresses through an organization to enable management to visualize the process, point out problems, and focus on the direction of a lean transformation.

Value Stream Mapping Basics (Product Development or Office)

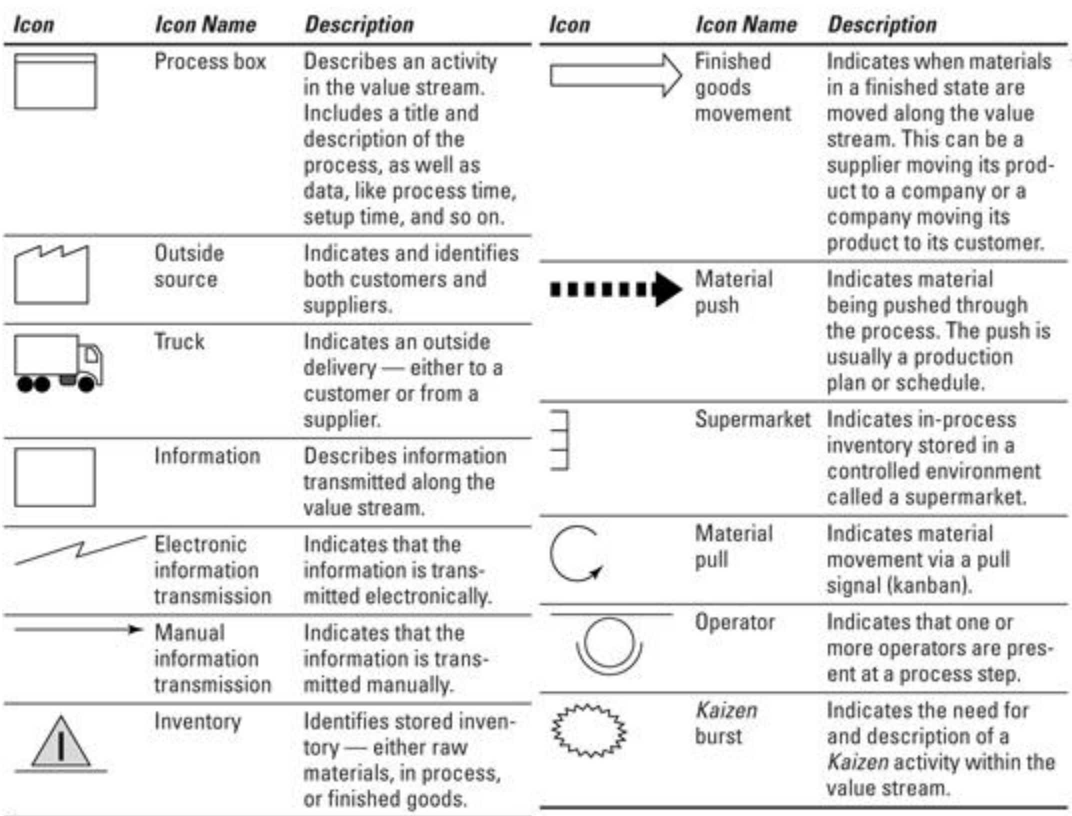
Value stream mapping is organized around seven basic activities:

1. Determine the product or service family – represent all of the work and transactions that the team seeks to change using the VSM tool.
2. Draw or collect the current documented state – represent the ways in which the company currently organizes and how work progresses through the process (current) by the documented work flow.
3. Draw the actual current state process map of how work is actually done, including workarounds. Walk through and/or follow this process to see how it actually completed. This will create the baseline condition.
4. Draw the future state map – focus on improvement efforts to eliminate waste and meet customer requirements.
5. Collect data – such as: process time, queue time, lead time, amount of rework created. This is done by entering data, retrieving data and analysis of the data (care need to be taken on the accuracy of the data). It is then added to current state map in bold.

6. Place kaizen burst on the current state map where there are gaps to bridge from the current to the future.
7. Prioritize kaizen ideas and implement.

Icons for Lean Value Stream Mapping

The *value stream map* (VSM) is a lean tool used to express and define the actions, information, timing, and events in the value stream. When create the VSM, use the conventions in the chart below for drawing the icons that illustrate an event, activity, or element. The standard icons used in a VSM are:



Icon	Icon Name	Description
	Process box	Describes an activity in the value stream. Includes a title and description of the process, as well as data, like process time, setup time, and so on.
	Outside source	Indicates and identifies both customers and suppliers.
	Truck	Indicates an outside delivery — either to a customer or from a supplier.
	Information	Describes information transmitted along the value stream.
	Electronic information transmission	Indicates that the information is transmitted electronically.
	Manual information transmission	Indicates that the information is transmitted manually.
	Inventory	Identifies stored inventory — either raw materials, in process, or finished goods.
	Finished goods movement	Indicates when materials in a finished state are moved along the value stream. This can be a supplier moving its product to a company or a company moving its product to its customer.
	Material push	Indicates material being pushed through the process. The push is usually a production plan or schedule.
	Supermarket	Indicates in-process inventory stored in a controlled environment called a supermarket.
	Material pull	Indicates material movement via a pull signal (kanban).
	Operator	Indicates that one or more operators are present at a process step.
	Kaizen burst	Indicates the need for and description of a *Kaizen* activity within the value stream.

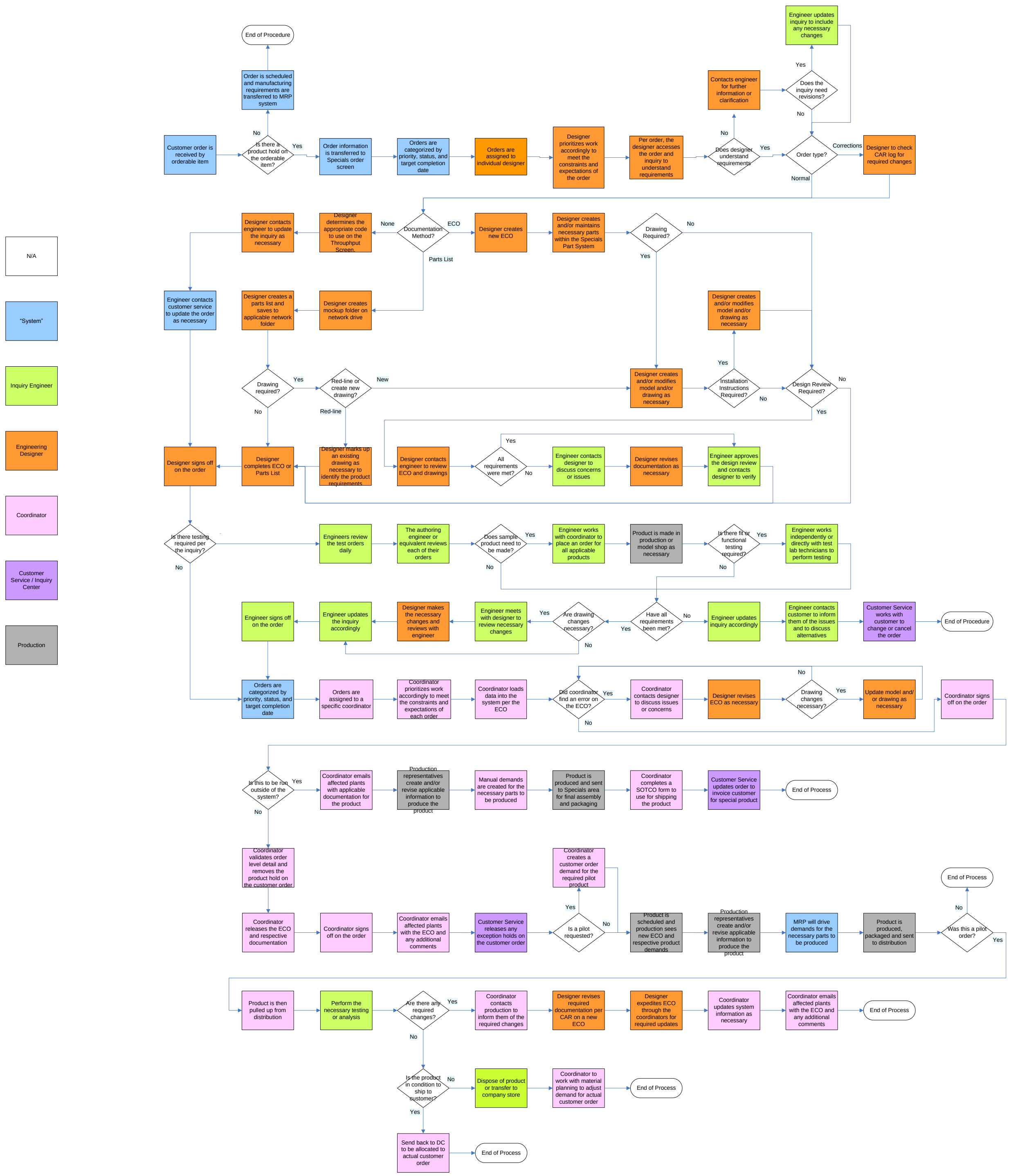
Reference: http://www.dummies.com/how-to/content/lean-for-dummies-cheat-sheet.html#ixzz17M9ov0Or, December 6, 2010.

Appendix C

Department Operational Procedure (DOP) 20.00

DOP 20.00 – SPECIALS ORDER PROCEDURE

Friday, September 19 2008



Appendix D

The Request for Quote from Customer

Dealership: Cime

Primary Contact:

ANNE MARIE LEGAULT

Phone: 514-451-8440

annemarie.legault@haworth.com

Fax:

Client Name: AXA

Secondary Contact:

Johanne Jourdain

Phone: 514-842-2463 x227

j.jourdain@cimedecor.ca

Fax:

Detail Line #1

Referencing standard product or existing special:	YGAF-6928R
With Special equivalent catalog part:	YGAF-6924R
Lamena:	N/A
This Special includes Haworth Veneer:	
Veneer Species:	VR - Walnut-Flat Cut
Veneer Finish:	VR-W12
This Special is not a Simple Stretch:	

Comments:
Adjust height of unit to 68" Adjust width of unit to 28" Total five (5) shelves in valet storage section, one (1) bar Previous special number SM05-0370 (right hand storage unit)

Files attached: 187169-1 vancouver 36in wide storage cabinet with double doors and file drawers.pdf 187169-1 vancouver storage unit - SM05-0670.pdf

file:////nahollap214/specials-inquiries/final/187/187169/inquiry 187169.htm [10/18/2010 9:51:19 AM]

Appendix E

The Comstar Page of a Custom Product Order

```
Page: 1  Document Name: Untitled
 COMSTAR - OPERATIONS              SPCL ORD DETAIL              (170410)
 COMMAND =>
 ORDER: 883441110     HEADER STATUS: ADD  DETAIL COUNT: ___3   ADDED: 11 JAN 11
   ORDER PRIORITY: 3  PO: 700154776                                BY: BATCH

 C INQ: __193237 LINE: ___8      STATUS: ADD _ QTY: _____1 DETAIL PRIORITY: 3
 SPCL: SPNE-381V   SPCL VALIDATION MASK: VCLR             ECO NUMBER: 011711
 ENGINEER: WBW3      DESIGN: DWC GLO3      BOM TECH: BOM ________  TYPE: N  725-23c
 SIMILAR TO #: X4FA-1830-NWFSSYLW,VCLR                  MFG#: RA792219
 BUT...: SEE SPECIAL FEATURE NOTES
 CATALOG EQUIVALENT: X4FA-1830-NWFSSYLW COMBINATION UNIT,RH BOX DRAWERS
 DESCRIPTION: MASTERS ATTACHED LATERAL FILE, WOOD.
              SPECIAL FEATURES: COMBINATION UNIT, LH SIDE FILE DRAWER AND  +
 SPECIFY    : WOOD & LR SPECIFICATION REQUIRED
 SHIP DATE  : 14 MAR 11  DESIGN GOAL: 28 JAN 11  DAYS: __7  SEE FOLDER: Y
   C  _999  QUOTE PREPARED BY: BILLI.WILLIAMS@HAWORTH.COM                E
   C  8991  NOTE THAT THIS INQUIRY IS PRICED PER WOOD GROUP 1.           E
   C  8992  FOR PRICING OF ALTERNATE GRADES, PLEASE CONTACT THE          E
   C  8993  INQUIRY CENTER OR LOOK UP USING ORDERLINE.  THIS SPECIAL     E
   C  8994  IS AVAILABLE IN THE FOLLOWING VENEER(S): VC, VJ, VP,         E

 ==   MODIFY   ==............................ S PP GLO3     28/01/11 07:56:13
 1-HELP 2-SELECT 3-QUIT 7-BACK 8-FORW 9-HEADER 10-DETAIL2 11-LINES 12-INQUIRY
 15-NOTES 20-PRODMAST 21-INQ-ORDS 24-ZOOM
4-©            1     IBMS390    10.64.2.76              TCP00635          6/2

Name: glo3 - Date: 1/28/2011  Time: 7:55:29 AM
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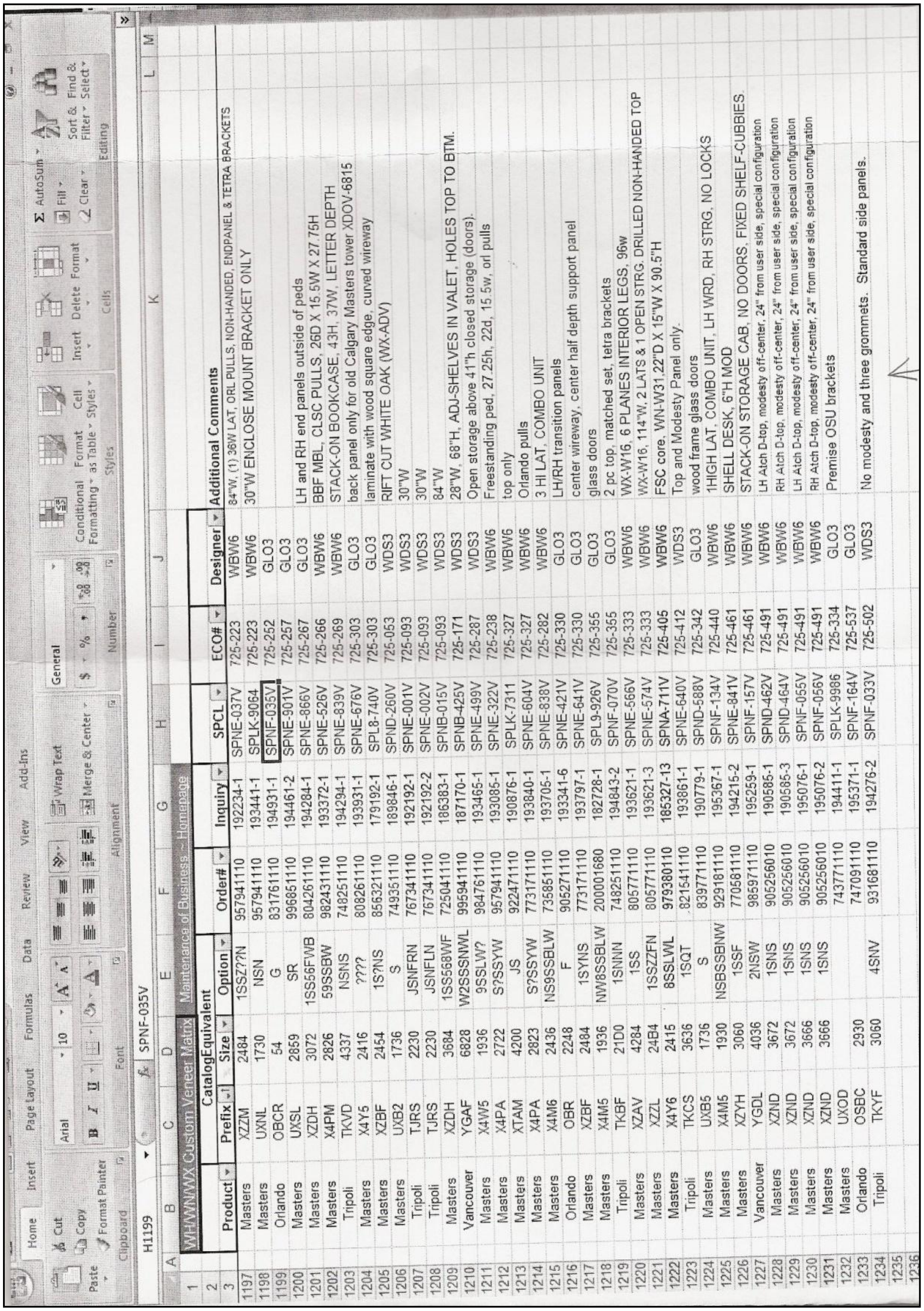
Appendix F

The Matrix of Similar Custom Products



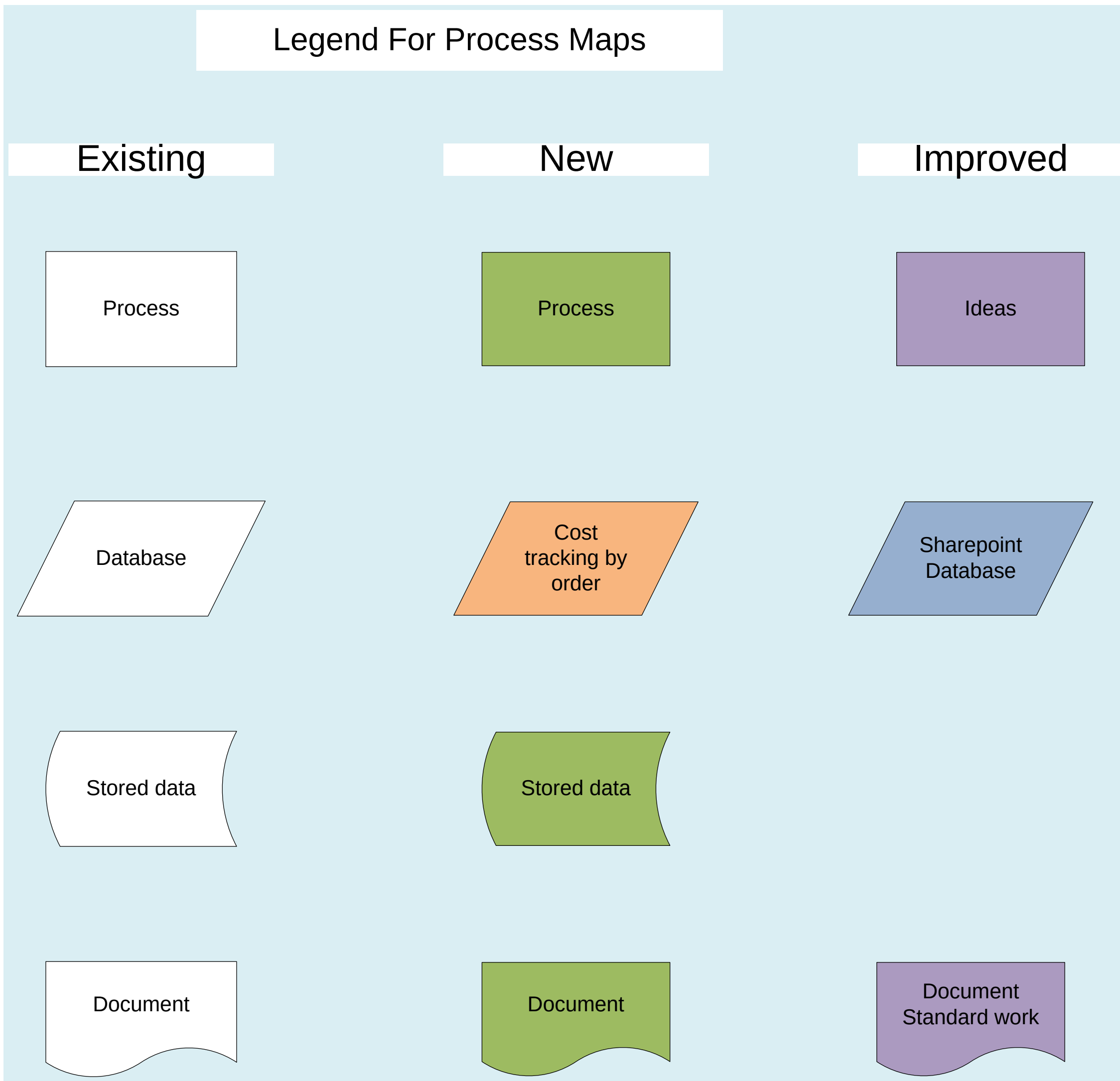
WH/WN/WX Custom Veneer Matrix — Maintenance of Business ~ Homepage

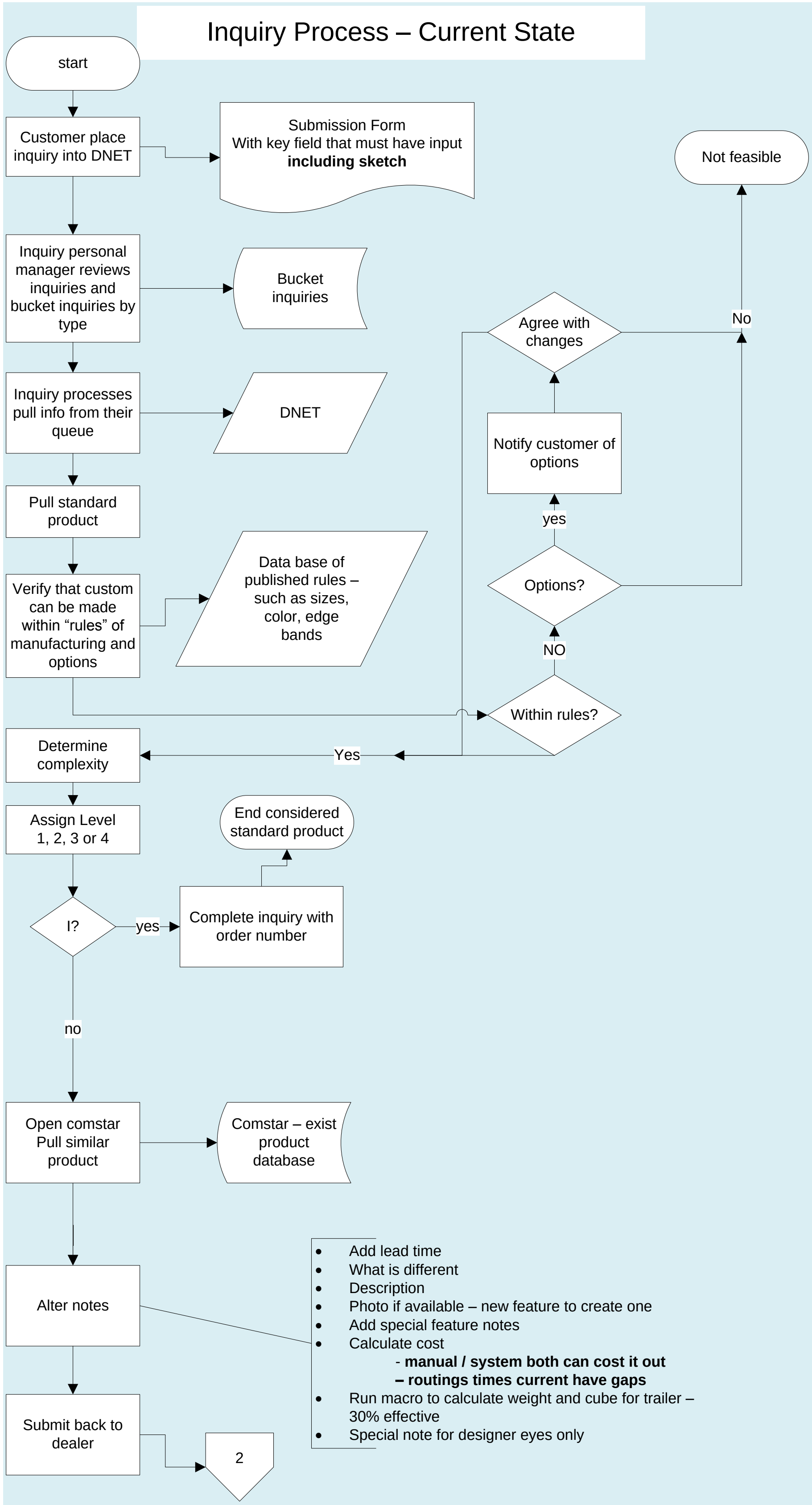
H1199 — SPNF-035V

Row	Product	Prefix (CatalogEquivalent)	Size (CatalogEquivalent)	Option (CatalogEquivalent)	Order#	Inquiry	SPCL	ECO#	Designer	Additional Comments
1197	Masters	XZZM	2484	1SSZ??N	957941110	192234-1	SPNE-037V	725-223	WBW6	84"W, (1) 36W LAT, ORL PULLS, NON-HANDED, ENDPANEL & TETRA BRACKETS
1198	Masters	UXNL	1730	NSN	957941110	193441-1	SPLK-9064	725-223	WBW6	30"W ENCLOSE MOUNT BRACKET ONLY
1199	Orlando	OBCR	54	G	831761110	194931-1	SPNF-035V	725-252	GLO3	
1200	Masters	UXSL	2859	SR	996851110	194461-2	SPNE-901V	725-257	GLO3	LH and RH end panels outside of peds
1201	Masters	XZDH	3072	1SS56FWB	804261110	194284-1	SPNE-866V	725-267	GLO3	BBF MBL, CLSC PULLS, 26D X 15.5W X 27.75H
1202	Masters	X4PM	2826	59SSBW	982431110	193372-1	SPNE-526V	725-266	WBW6	STACK-ON BOOKCASE, 43H, 37W, LETTER DEPTH
1203	Tripoli	TKVD	4337	NSNS	748251110	194294-1	SPNE-839V	725-269	WBW6	back panel only for old Calgary Masters tower XDOV-6815
1204	Masters	X4Y5	2416	????	808261110	193931-1	SPNE-676V	725-303	GLO3	laminate with wood square edge, curved wireway
1205	Masters	XZBF	2454	1S?NS	856321110	179192-1	SPL8-740V	725-303	GLO3	RIFT CUT WHITE OAK (WX-ADV)
1206	Masters	UXB2	1736	S	749351110	189846-1	SPND-260V	725-053	WDS3	30"W
1207	Tripoli	TJRS	2230	JSNFRN	767341110	192192-1	SPNE-001V	725-093	WDS3	30"W
1208	Tripoli	TJRS	2230	JSNFLN	767341110	192192-2	SPNE-002V	725-093	WDS3	84"W
1209	Masters	XZDH	3684	1SS568WF	725041110	186383-1	SPNB-015V	725-093	WDS3	28"W, 68"H, ADJ-SHELVES IN VALET, HOLES TOP TO BTM.
1210	Vancouver	YGAF	6828	W2SSSNWL	995941110	187170-1	SPNB-425V	725-171	WDS3	Open storage above 41"h closed storage (doors).
1211	Masters	X4W5	1936	9SSLW?	984761110	193465-1	SPNE-499V	725-287	WDS3	Freestanding ped, 27.25h, 22d, 15.5w, orl pulls
1212	Masters	X4PA	2722	S?SSYW	957941110	193085-1	SPNE-322V	725-238	WBW6	top only
1213	Masters	XTAM	4200	JS	922471110	190876-1	SPLK-7311	725-327	WBW6	Orlando pulls
1214	Masters	X4PA	2823	S?SSYW	773171110	193840-1	SPNE-604V	725-327	WBW6	3 HI LAT, COMBO UNIT
1215	Masters	X4M6	2436	NS9SSBLW	735851110	193705-1	SPNE-838V	725-282	WBW6	LH/RH transition panels
1216	Orlando	OBR	2248	F	905271110	193341-6	SPNE-421V	725-330	GLO3	center wireway, center half depth support panel
1217	Masters	XZBF	2484	1SYNS	773171110	193797-1	SPNE-641V	725-330	GLO3	glass doors
1218	Masters	X4M5	1936	NW8SSBLW	200001680	182728-1	SPL9-926V	725-355	GLO3	2 pc top, matched set, tetra brackets
1219	Tripoli	TKBF	21D0	1SNNN	748251110	194843-2	SPNF-070V	725-355	GLO3	WX-W16, 6 PLANES INTERIOR LEGS, 96w
1220	Masters	XZAV	4284	1SS	805771110	193621-1	SPNE-566V	725-333	WBW6	WX-W16, 114"W, 2 LATS & 1 OPEN STRG. DRILLED NON-HANDED TOP
1221	Masters	XZZL	24B4	1SSZZFN	805771110	193621-3	SPNE-574V	725-333	WBW6	FSC core, WN-W31,22"D X 15"W X 90.5"H
1222	Masters	X4Y6	2415	8SSLWL	979380110	185327-13	SPNA-711V	725-405	WBW6	Top and Modesty Panel only.
1223	Tripoli	TKCS	3636	1SQT	821541110	193861-1	SPNE-640V	725-412	WDS3	wood frame glass doors
1224	Masters	UXB5	1736	S	839771110	190779-1	SPND-588V	725-342	GLO3	1HIGH LAT, COMBO UNIT, LH WRD, RH STRG, NO LOCKS
1225	Masters	X4M5	1930	NSBSSBNW	929181110	195367-1	SPNF-134V	725-440	WBW6	SHELL DESK, 6"H MOD
1226	Masters	XZYH	3060	1SSF	770581110	194215-2	SPNE-841V	725-461	WBW6	STACK-ON STORAGE CAB, NO DOORS, FIXED SHELF-CUBBIES.
1227	Vancouver	YGDL	4036	2NSW	985971110	195259-1	SPNF-157V	725-461	WBW6	LH Atch D-top, modesty off-center, 24" from user side, special configuration
1228	Masters	XZND	3672	1SNS	905256010	190585-1	SPND-462V	725-491	WBW6	RH Atch D-top, modesty off-center, 24" from user side, special configuration
1229	Masters	XZND	3672	1SNS	905256010	190585-3	SPND-464V	725-491	WBW6	LH Atch D-top, modesty off-center, 24" from user side, special configuration
1230	Masters	XZND	3666	1SNS	905256010	195076-1	SPNF-055V	725-491	WBW6	RH Atch D-top, modesty off-center, 24" from user side, special configuration
1231	Masters	XZND	3666	1SNS	905256010	195076-2	SPNF-056V	725-491	WBW6	Premise OSU brackets
1232	Masters	UXOD			743771110	194411-1	SPLK-9986	725-334	GLO3	
1233	Orlando	OSBC	2930		747091110	195371-1	SPNF-164V	725-537	GLO3	
1234	Tripoli	TKYF	3060	4SNV	931681110	194276-2	SPNF-033V	725-502	WDS3	No modesty and three grommets. Standard side panels.

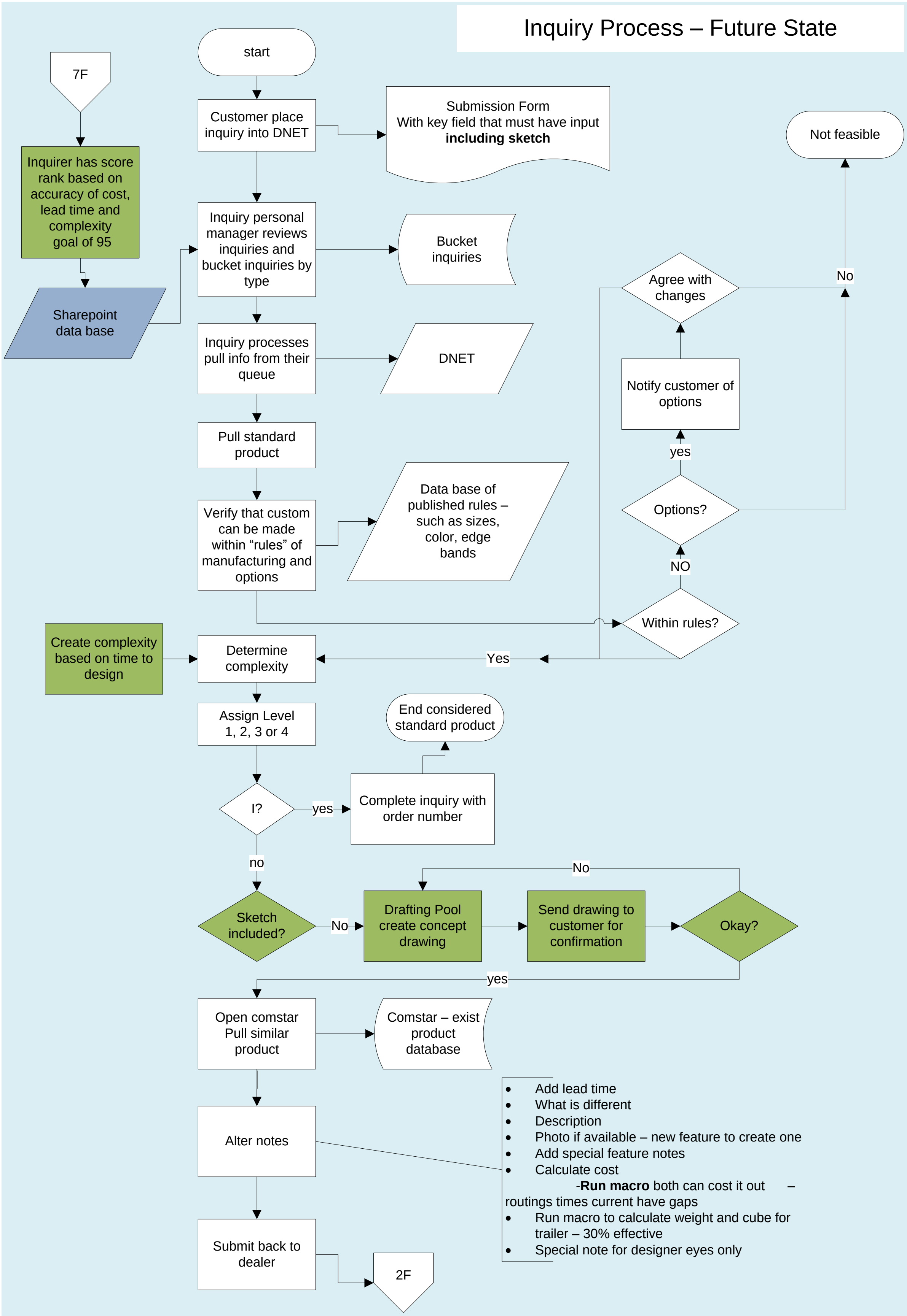
Appendix G

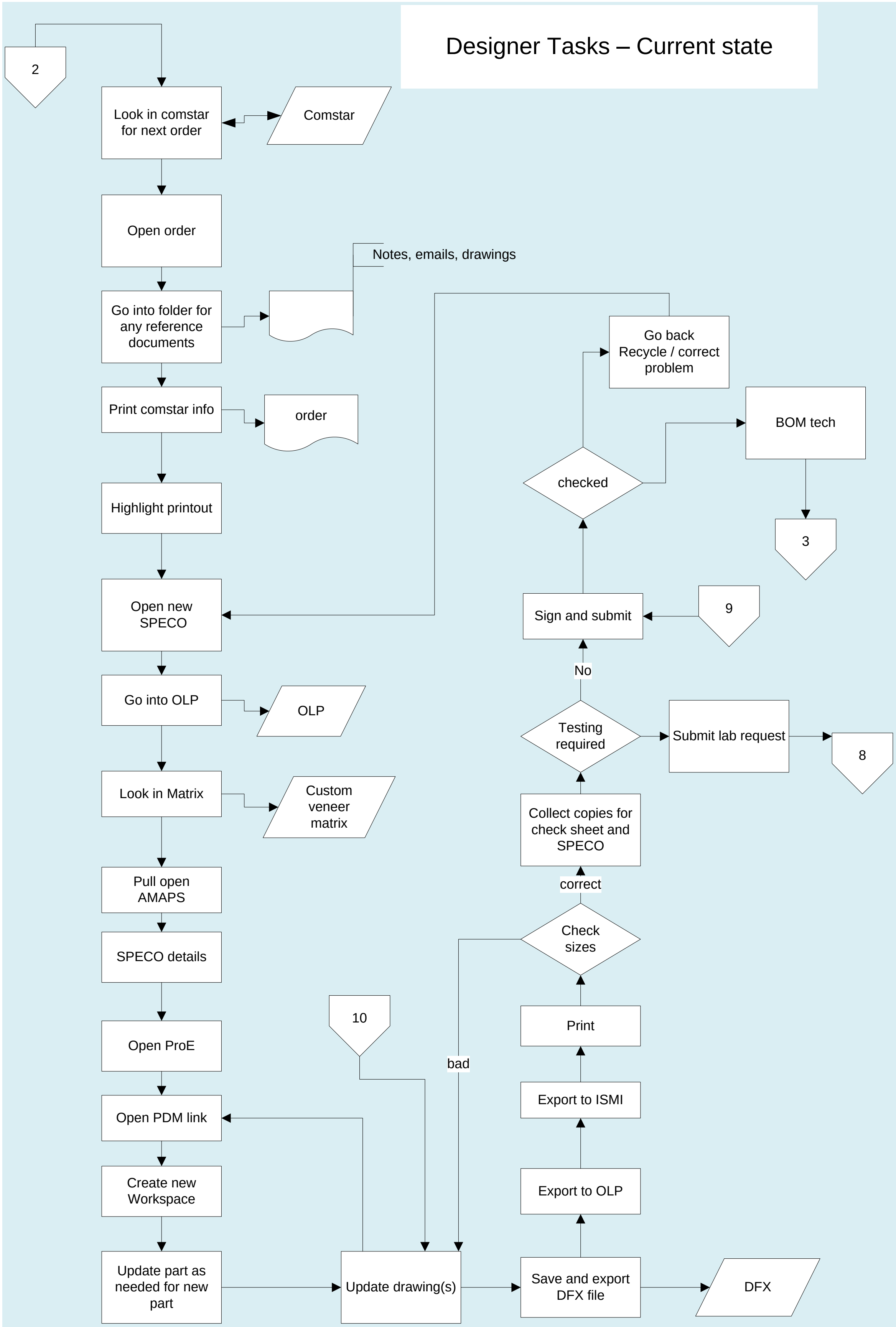
Process Flows Maps

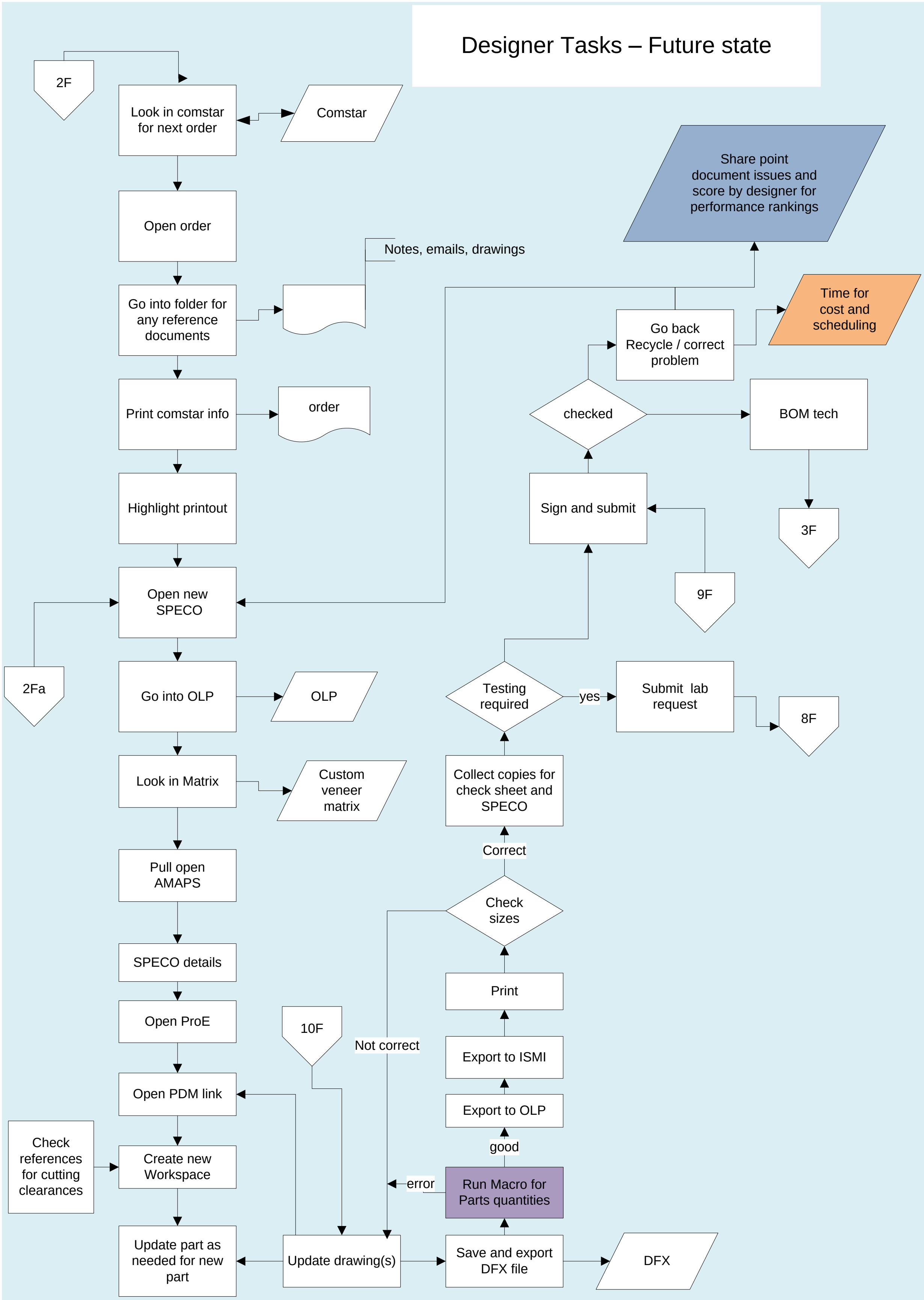


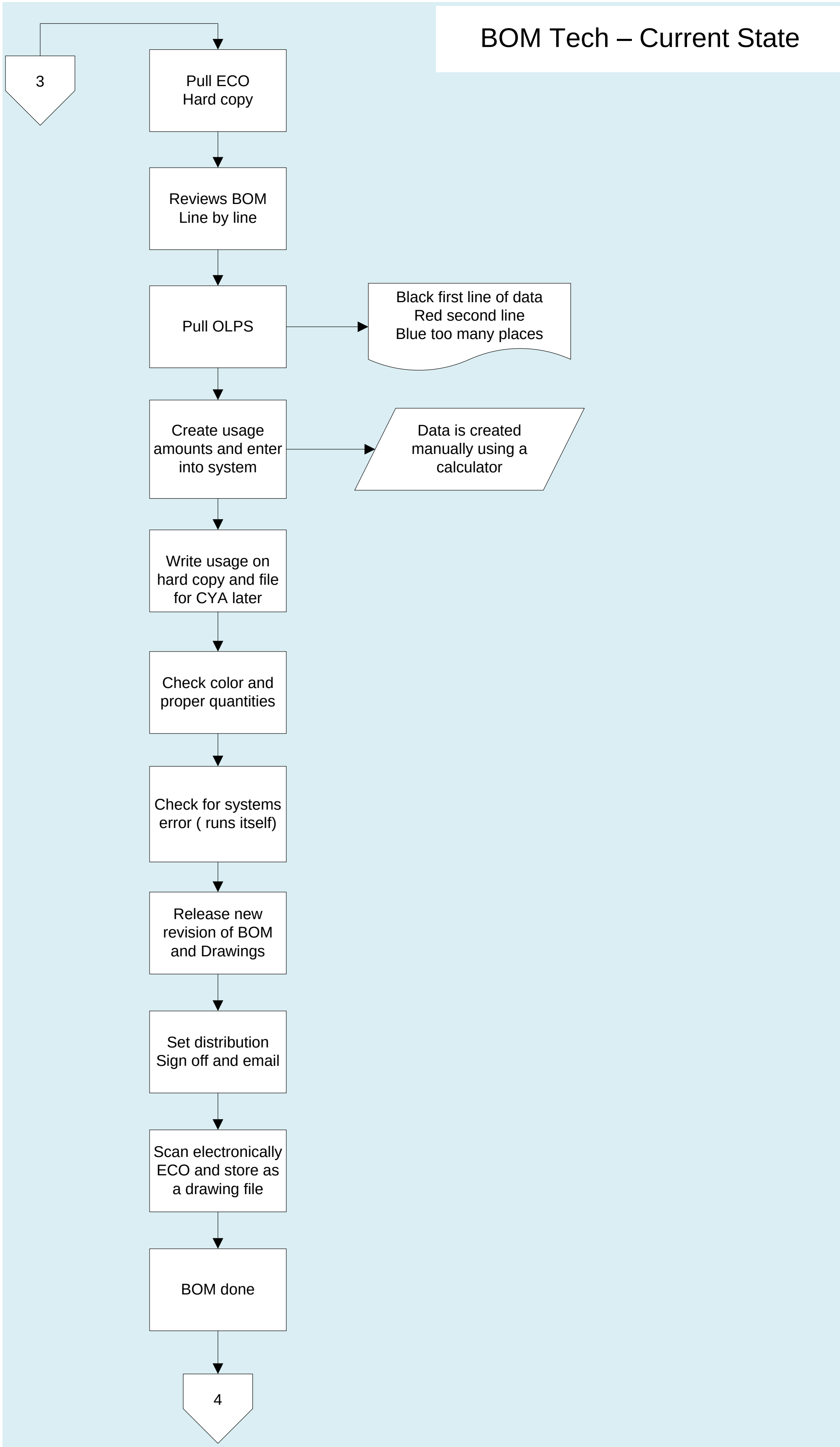


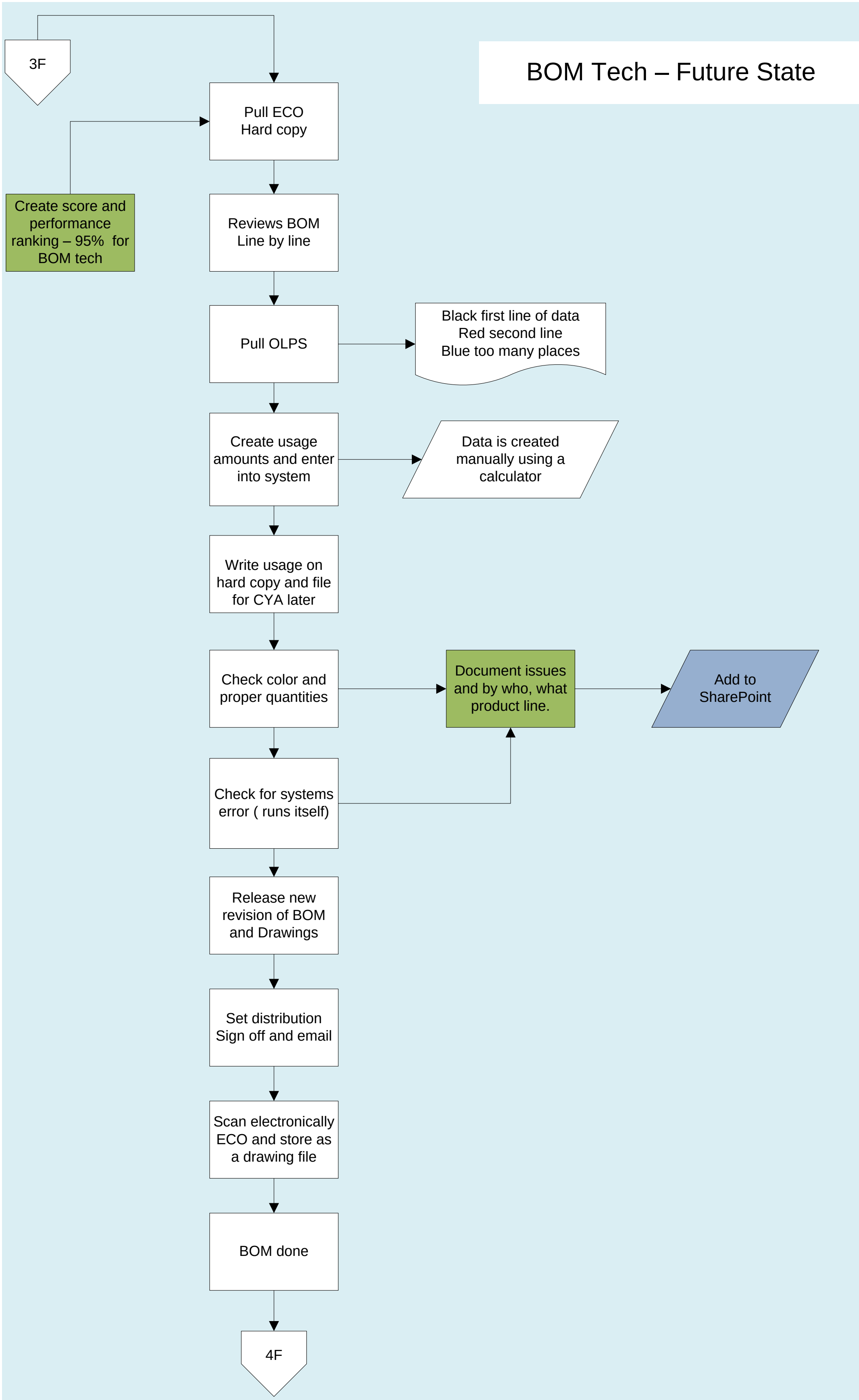
Inquiry Process – Current State
start
Customer place inquiry into DNET
Submission Form
With key field that must have input
including sketch
Not feasible
Inquiry personal manager reviews inquiries and bucket inquiries by type
Bucket inquiries
Agree with changes
No
Inquiry processes pull info from their queue
DNET
Notify customer of options
Pull standard product
yes
Verify that custom can be made within "rules" of manufacturing and options
Data base of published rules – such as sizes, color, edge bands
Options?
NO
Within rules?
Determine complexity
Yes
Assign Level 1, 2, 3 or 4
End considered standard product
I?
yes
Complete inquiry with order number
no
Open comstar Pull similar product
Comstar – exist product database
Alter notes
• Add lead time
• What is different
• Description
• Photo if available – new feature to create one
• Add special feature notes
• Calculate cost
- **manual / system both can cost it out**
– routings times current have gaps
• Run macro to calculate weight and cube for trailer – 30% effective
• Special note for designer eyes only
Submit back to dealer
2

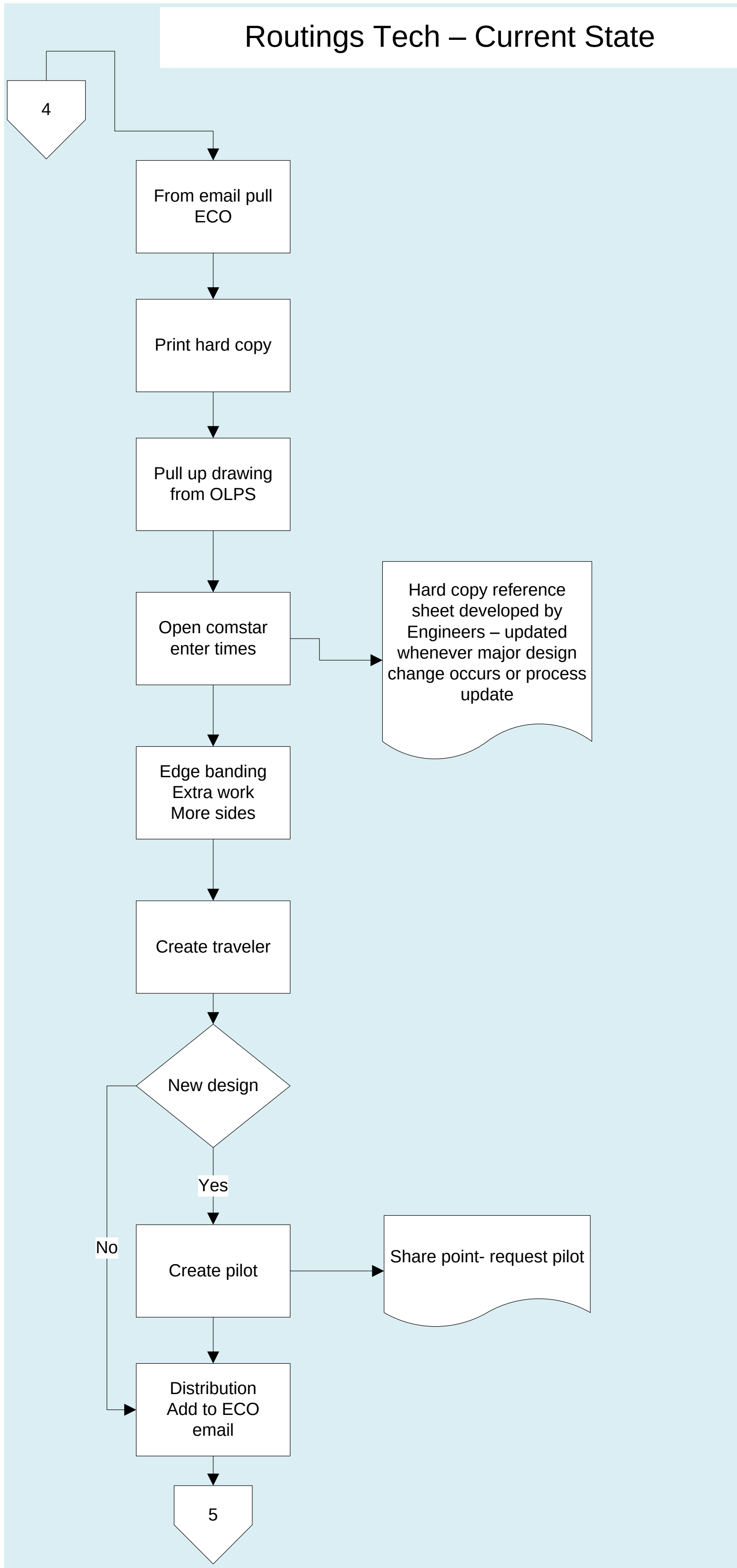

Inquiry Process – Future State
7F
Inquirer has score rank based on accuracy of cost, lead time and complexity goal of 95
Sharepoint data base
start
Customer place inquiry into DNET
Submission Form With key field that must have input **including sketch**
Inquiry personal manager reviews inquiries and bucket inquiries by type
Bucket inquiries
Inquiry processes pull info from their queue
DNET
Pull standard product
Verify that custom can be made within "rules" of manufacturing and options
Data base of published rules – such as sizes, color, edge bands
Not feasible
Agree with changes
No
Notify customer of options
yes
Options?
NO
Within rules?
Create complexity based on time to design
Determine complexity
Yes
Assign Level 1, 2, 3 or 4
End considered standard product
I?
yes
Complete inquiry with order number
no
No
Sketch included?
No
Drafting Pool create concept drawing
Send drawing to customer for confirmation
Okay?
yes
Open comstar Pull similar product
Comstar – exist product database
Alter notes
Submit back to dealer
2F
• Add lead time
• What is different
• Description
• Photo if available – new feature to create one
• Add special feature notes
• Calculate cost
-**Run macro** both can cost it out – routings times current have gaps
• Run macro to calculate weight and cube for trailer – 30% effective
• Special note for designer eyes only

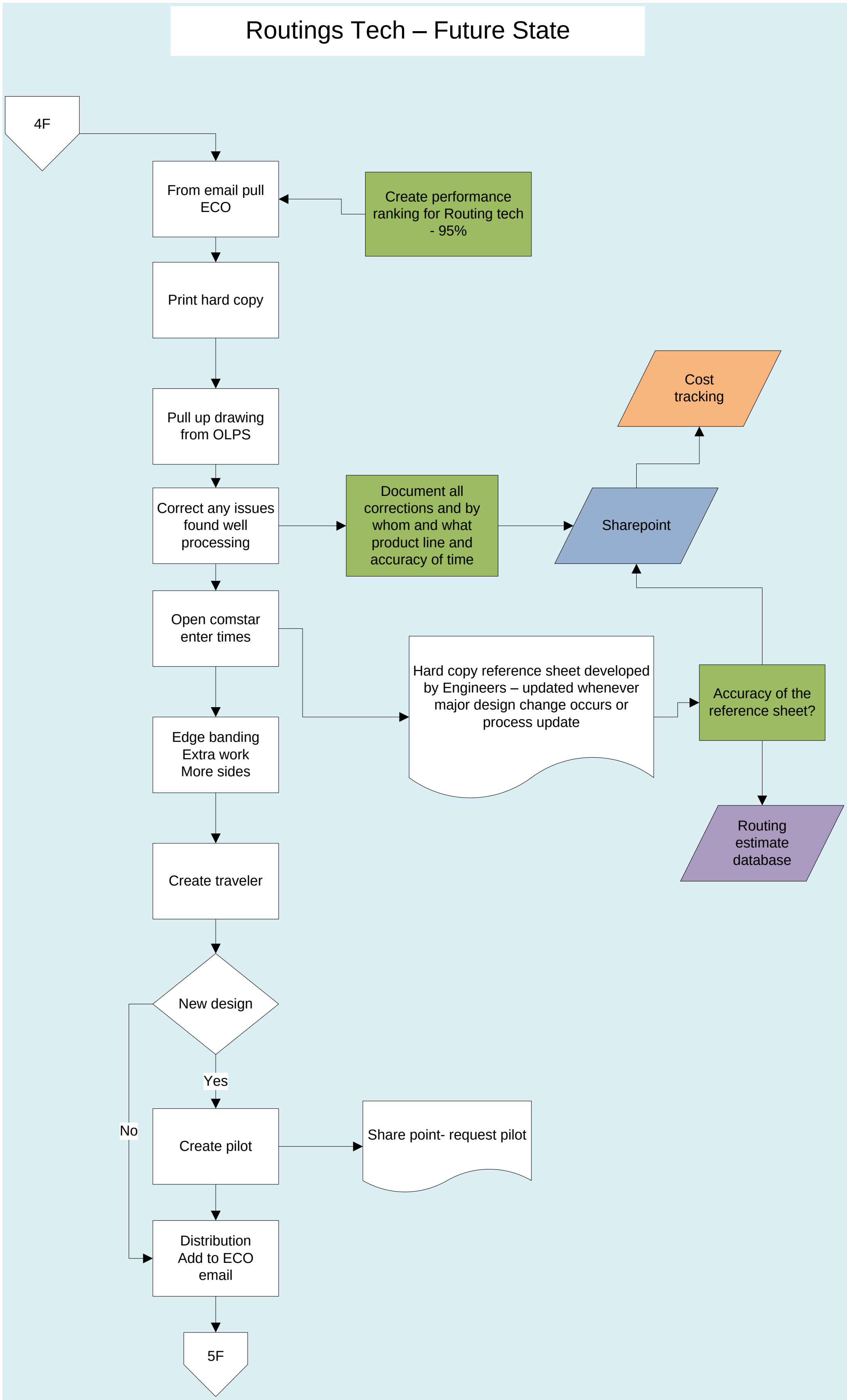

Designer Tasks – Current state
2
Look in comstar for next order
Comstar
Open order
Notes, emails, drawings
Go into folder for any reference documents
Print comstar info
order
Highlight printout
Open new SPECO
Go into OLP
OLP
Look in Matrix
Custom veneer matrix
Pull open AMAPS
SPECO details
Open ProE
Open PDM link
Create new Workspace
Update part as needed for new part
10
Update drawing(s)
bad
Save and export DFX file
DFX
Export to OLP
Export to ISMI
Print
Check sizes
correct
Collect copies for check sheet and SPECO
Testing required
Submit lab request
8
No
Sign and submit
9
checked
Go back Recycle / correct problem
BOM tech
3

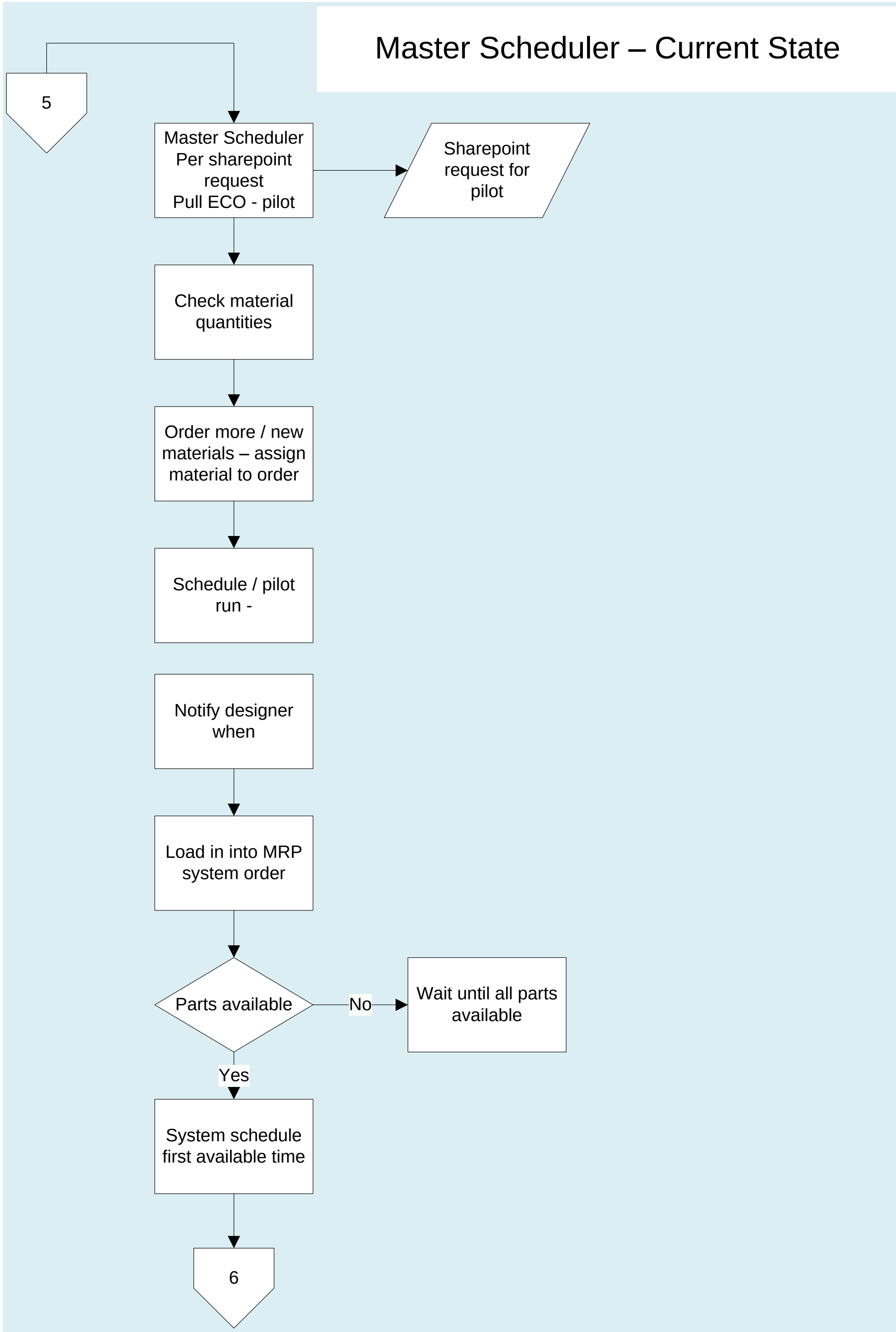

Designer Tasks – Future state
2F
Look in comstar for next order
Comstar
Open order
Go into folder for any reference documents
Notes, emails, drawings
Print comstar info
order
Highlight printout
Open new SPECO
2Fa
Go into OLP
OLP
Look in Matrix
Custom veneer matrix
Pull open AMAPS
SPECO details
Open ProE
Open PDM link
Check references for cutting clearances
Create new Workspace
Update part as needed for new part
10F
Update drawing(s)
Not correct
Save and export DFX file
DFX
Run Macro for Parts quantities
error
good
Export to OLP
Export to ISMI
Print
Check sizes
Correct
Collect copies for check sheet and SPECO
Testing required
yes
Submit lab request
8F
9F
Sign and submit
checked
BOM tech
3F
Go back Recycle / correct problem
Time for cost and scheduling
Share point document issues and score by designer for performance rankings

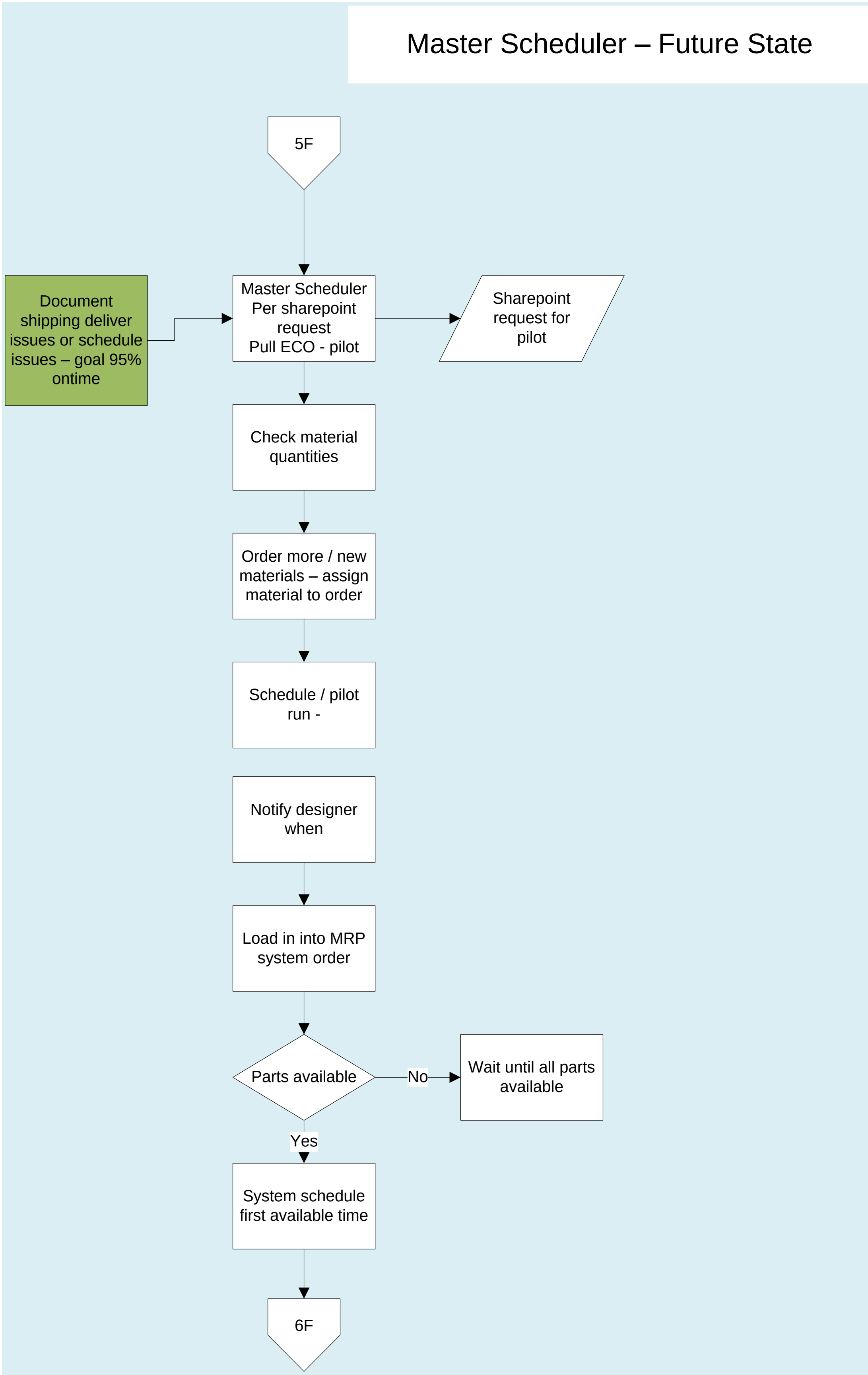

BOM Tech – Current State
3
Pull ECO
Hard copy
Reviews BOM
Line by line
Pull OLPS
Black first line of data
Red second line
Blue too many places
Create usage amounts and enter into system
Data is created manually using a calculator
Write usage on hard copy and file for CYA later
Check color and proper quantities
Check for systems error (runs itself)
Release new revision of BOM and Drawings
Set distribution
Sign off and email
Scan electronically ECO and store as a drawing file
BOM done
4

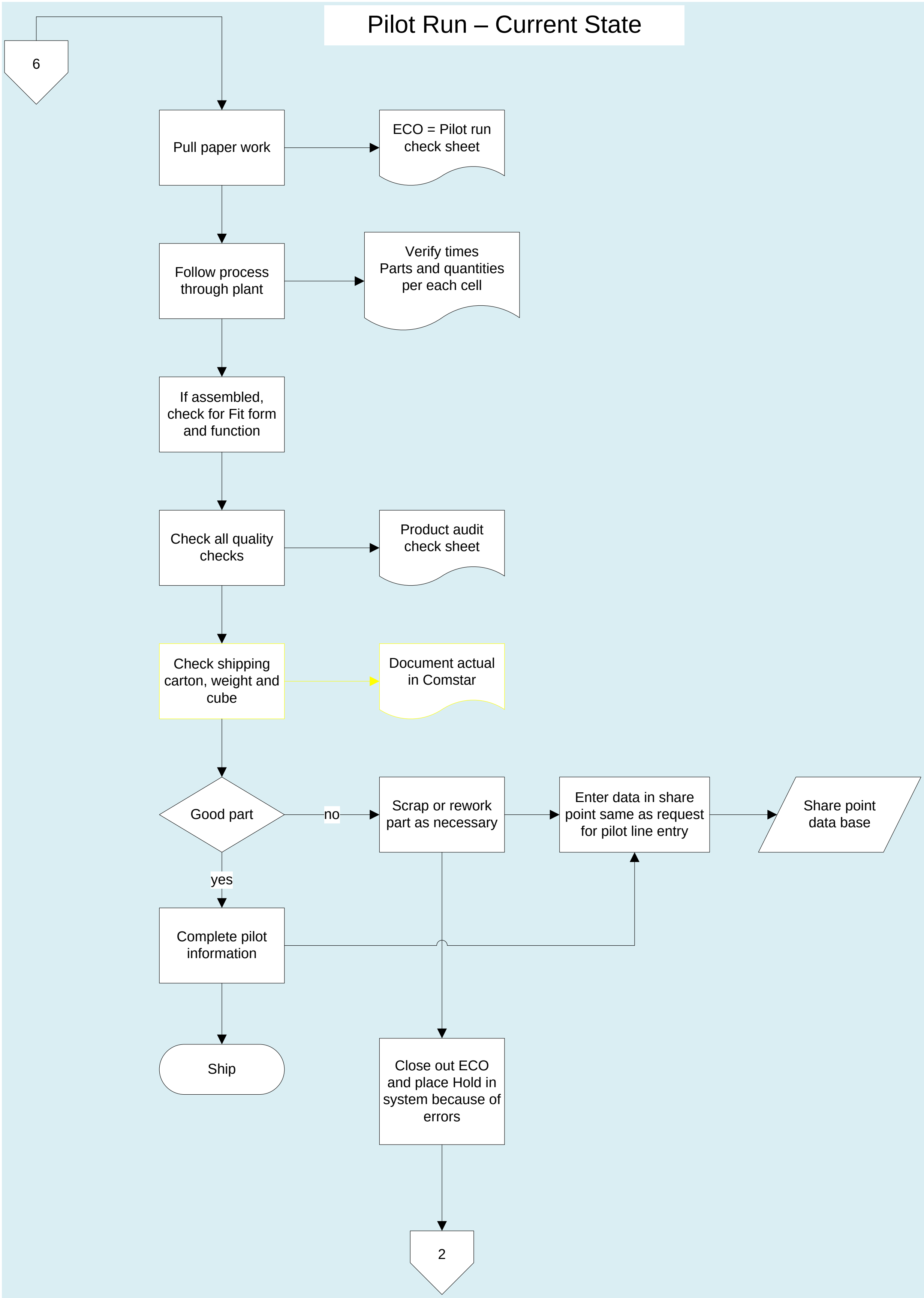

BOM Tech – Future State
3F
Pull ECO Hard copy
Create score and performance ranking – 95% for BOM tech
Reviews BOM Line by line
Pull OLPS
Black first line of data
Red second line
Blue too many places
Create usage amounts and enter into system
Data is created manually using a calculator
Write usage on hard copy and file for CYA later
Check color and proper quantities
Document issues and by who, what product line.
Add to SharePoint
Check for systems error (runs itself)
Release new revision of BOM and Drawings
Set distribution Sign off and email
Scan electronically ECO and store as a drawing file
BOM done
4F

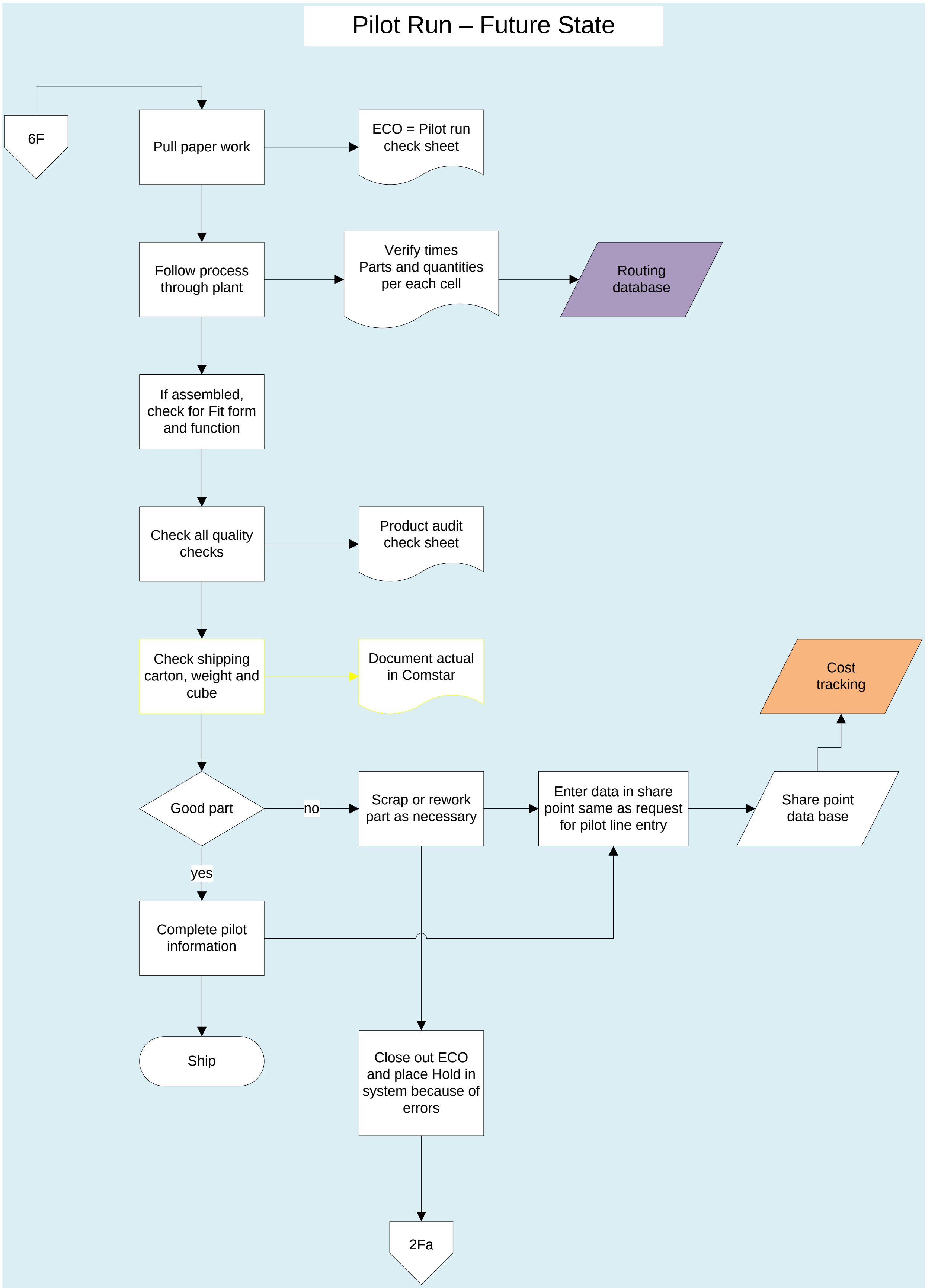

Routings Tech – Current State
4
From email pull ECO
Print hard copy
Pull up drawing from OLPS
Open comstar enter times
Hard copy reference sheet developed by Engineers – updated whenever major design change occurs or process update
Edge banding Extra work More sides
Create traveler
New design
Yes
No
Create pilot
Share point- request pilot
Distribution Add to ECO email
5

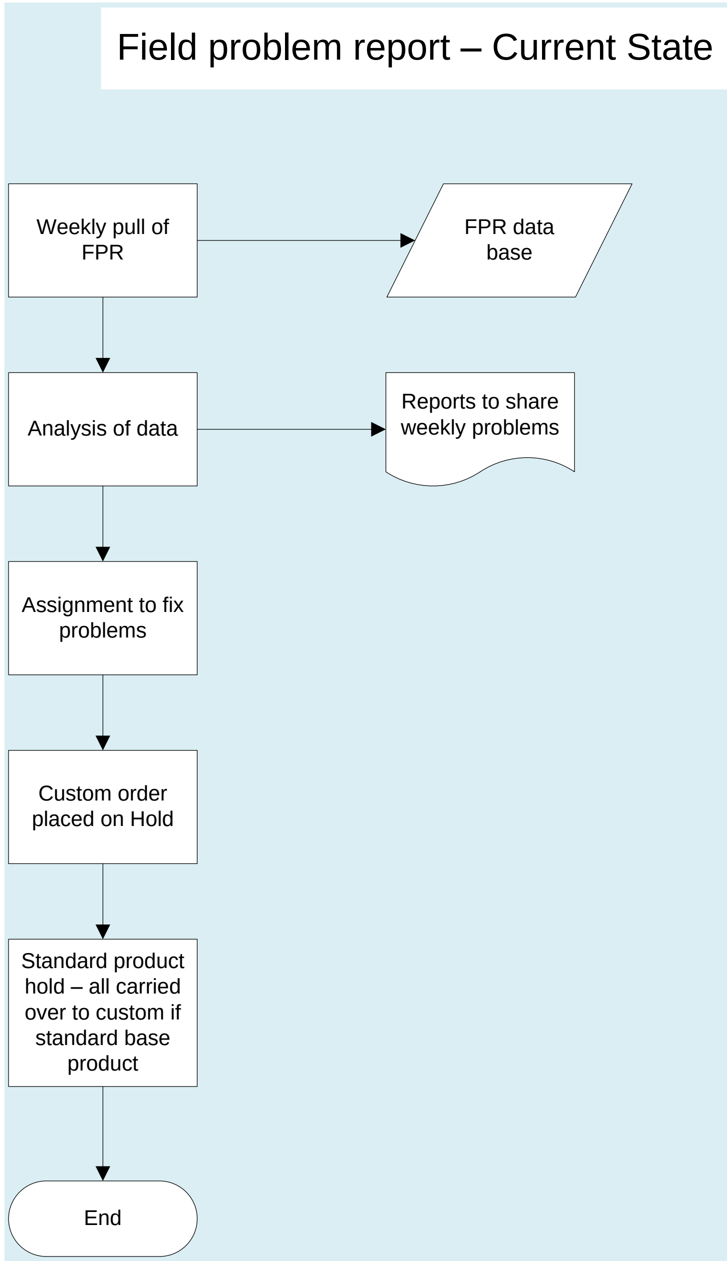

Routings Tech – Future State
4F
From email pull ECO
Create performance ranking for Routing tech - 95%
Print hard copy
Cost tracking
Pull up drawing from OLPS
Correct any issues found well processing
Document all corrections and by whom and what product line and accuracy of time
Sharepoint
Open comstar enter times
Hard copy reference sheet developed by Engineers – updated whenever major design change occurs or process update
Accuracy of the reference sheet?
Edge banding Extra work More sides
Routing estimate database
Create traveler
New design
Yes
No
Create pilot
Share point- request pilot
Distribution Add to ECO email
5F

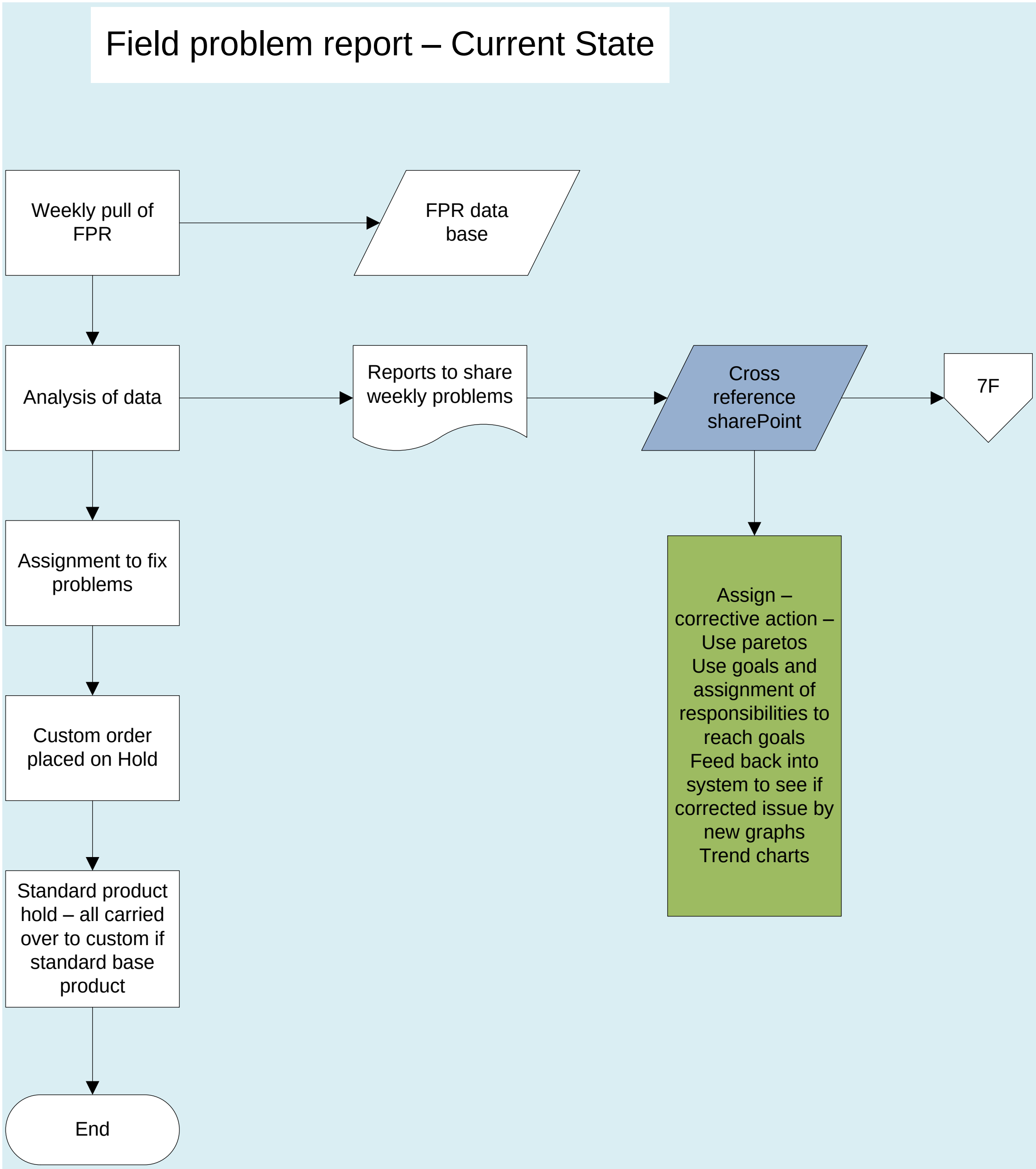

Master Scheduler – Current State
5
Master Scheduler Per sharepoint request Pull ECO - pilot
Sharepoint request for pilot
Check material quantities
Order more / new materials – assign material to order
Schedule / pilot run -
Notify designer when
Load in into MRP system order
Parts available
No
Wait until all parts available
Yes
System schedule first available time
6

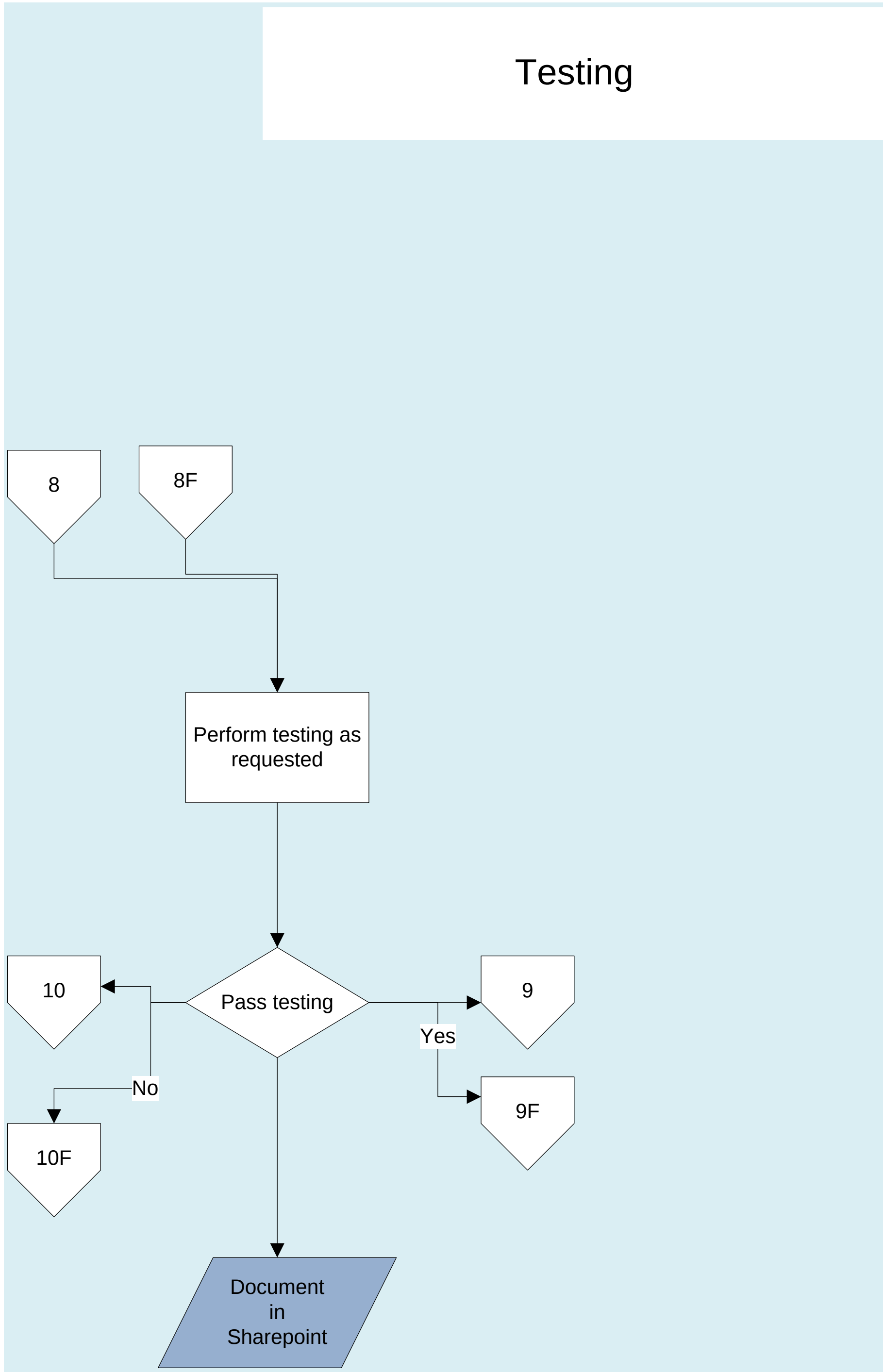

Master Scheduler – Future State
5F
Document shipping deliver issues or schedule issues – goal 95% ontime
Master Scheduler Per sharepoint request Pull ECO - pilot
Sharepoint request for pilot
Check material quantities
Order more / new materials – assign material to order
Schedule / pilot run -
Notify designer when
Load in into MRP system order
Parts available
No
Wait until all parts available
Yes
System schedule first available time
6F


Pilot Run – Current State
6
Pull paper work
ECO = Pilot run check sheet
Follow process through plant
Verify times Parts and quantities per each cell
If assembled, check for Fit form and function
Check all quality checks
Product audit check sheet
Check shipping carton, weight and cube
Document actual in Comstar
Good part
no
Scrap or rework part as necessary
Enter data in share point same as request for pilot line entry
Share point data base
yes
Complete pilot information
Ship
Close out ECO and place Hold in system because of errors
2


Pilot Run – Future State
6F
Pull paper work
ECO = Pilot run check sheet
Follow process through plant
Verify times Parts and quantities per each cell
Routing database
If assembled, check for Fit form and function
Check all quality checks
Product audit check sheet
Check shipping carton, weight and cube
Document actual in Comstar
Cost tracking
Good part
no
Scrap or rework part as necessary
Enter data in share point same as request for pilot line entry
Share point data base
yes
Complete pilot information
Ship
Close out ECO and place Hold in system because of errors
2Fa


Field problem report – Current State
Weekly pull of FPR
FPR data base
Analysis of data
Reports to share weekly problems
Assignment to fix problems
Custom order placed on Hold
Standard product hold – all carried over to custom if standard base product
End


Field problem report – Current State
Weekly pull of FPR
FPR data base
Analysis of data
Reports to share weekly problems
Cross reference sharePoint
7F
Assignment to fix problems
Assign – corrective action – Use paretos Use goals and assignment of responsibilities to reach goals Feed back into system to see if corrected issue by new graphs Trend charts
Custom order placed on Hold
Standard product hold – all carried over to custom if standard base product
End


Testing
8
8F
Perform testing as requested
10
Pass testing
9
Yes
No
9F
10F
Document in Sharepoint

Appendix H

Routing Reference Sheet

W/C Description	WC ID	Oper. #	Small 0-24"	Medium 25"-48"	Large 49"-71"	Xlarge 72" and up	Emp Run #	Notes
Panel Receiving	11015	Oper 002000	0.0102	0.0102	0.01633	0.02433	1	Everything
Fronts Net Size Route	22005	Oper 002400	0.065	0.065	0.065	0.065	1	**Front Sets - IF FINGER PULL SEE TAB 'FINGER PULL TIMES'**
Net Size Route	22015	Oper 002500	0.0479	0.0479	0.0479	0.0479	1	Casegood parts
RF Net Size and Route	22020	Oper 002600	0.123	0.123	0.123	0.123	1	Curved tops
Edgebanding	22025	Oper 003000	0.08	0.08	0.2	0.2	1	**IF FINGER PULL SEE TAB 'FINGER PULL TIMES'**
Finger Pull	22035	Oper 003100					1	**SEE TAB 'FINGER PULL TIMES'**
RF/Route/Shape	22045	Oper 003200	0.267	0.62	0.75	1.1	1	**IF FINGER PULL SEE TAB 'FINGER PULL TIMES'**
Custom Specials	22055	Oper 003300					1	Certain parts - Part Dependant
Post Edgeband Route	22030	Oper 003400	0.05	0.05	0.05	0.05	1	Certain parts
ISIR Required	22060	Oper 003500	0.00001	0.00001	0.00001	0.00001	1	Everything first time it is ran
White Wood Machine Sand	33025	Oper 004000	0.04	0.04	0.08	0.08	1	Parts large enough to require help need the additional time allotted.
White Wood Hand Sand	33035	Oper 004100	0.0255	0.03	0.036	0.0432	1	**Tops - Heavy Lumber - NOT CURRENTLY USED**
White Wood Stage	33015	Oper 004200	0.00001	0.00001	0.00001	0.00001	1	Includes Hand Sanding of Edges
Stain	44015	Oper 004500	0.0441	0.0441	0.1055	0.1055	1	
Clear Coat	44035	Oper 005000					1	**See Tab 'Clear Coat times'**
Kitting	44055	Oper 005500	0.4057	0.4057	0.4057	0.4057	1	
Auto Bore and Dowel	55025	Oper 005700	0.0155	0.0177	0.0252	0.0252	1	
MTV Assembly	55035	Oper 005800	0.65	0.65	0.65	0.65	1	
Flat Panel Pack	66015	Oper 006000	0.1	0.1	0.1	0.1	1	
Casegood Pack	66025	Oper 006500	0.1167	0.1167	0.2	0.2	1	
MTVO Service Parts	66035	Oper 006600	0.083	0.083	0.2	0.2	1	
Dummy Routing - Count	99999	Oper 006700	0.00001	0.00001	0.00001	0.00001	1	Everything

Seconds Small	Seconds Medium	Seconds Large	Seconds Xlarge	AMAPS Conv F.	W/C Description	Machine Staffing	Team Leader	Total Staffing	Cycle Time Small	Cycle Time Medium	Cycle Time Large	Cycle Time Xlarge
37	37	59	88	3600	Panel Receiving	1	0.11	1.11	33.081081	33.081081	52.962162	78.908108
234	234	234	234	3600	Fronts Net Size Route	1	0.17	1.17	200	200	200	200
172	172	172	172	3600	Net Size Route	1	0.17	1.17	147.38462	147.38462	147.38462	147.38462
443	443	443	443	3600	RF Net Size and Route	1	0.13	1.13	391.85841	391.85841	391.85841	391.85841
288	288	720	720	3600	Edgebanding	2	0.33	2.33	123.60515	123.60515	309.01288	309.01288
0	0	0	0	3600	Finger Pull	1	0.13	1.13	0	0	0	0
961	2232	2700	3960	3600	RF/Route/Shape	2	0.13	2.13	451.26761	1047.8873	1267.6056	1859.1549
0	0	0	0	3600	Custom Specials			0				
180	180	180	180	3600	Post Edgeband Route	1	0	1	180	180	180	180
0	0	0	0	3600	ISIR Required	0	0	0	0	0	0	0
144	144	288	288	3600	White Wood Machine Sand	3	0.33	3.33	43.243243	43.243243	86.486486	86.486486
92	108	130	156	3600	White Wood Hand Sand	1	0.02	1.02	90	105.88235	127.05882	152.47059
0	0	0	0	3600	White Wood Stage	1	0.02	1.02	0.0352941	0.0352941	0.0352941	0.0352941
159	159	380	380	3600	Stain	6	0.33	6.33	25.080569	25.080569	60	60
0	0	0	0	3600	Clear Coat	15	0.33	15.33	0	0	0	0
1461	1461	1461	1461	3600	Kitting							
56	64	91	91	3600	Auto Bore and Dowel							
2340	2340	2340	2340	3600	MTV Assembly							
360	360	360	360	3600	Flat Panel Pack							
420	420	720	720	3600	Casegood Pack							
299	299	720	720	3600	MTVO Service Parts							
0	0	0	0	3600	Dummy Routing - Count							

Appendix I

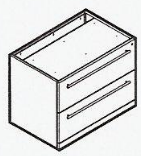
The Cataloged Standard Product

Masters Series — Wood Finish

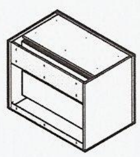
Attached Lateral Files

Two-High Attached Lateral File — Wood

Height	Open Back Depth	Full Back Depth	Width	Number	❶❷	❸	Wood Finish Group 1	2	3	4
Letter Depth										
28" (710mm)	18" (457mm)	18 ¾" (476mm)	30" (762mm)	X4FA-1830- N	S S	L W	$1505	$1565	$1625	$1716
			36" (914mm)	X4FA-1836- N	S S	L W	1620	1685	1750	1847
	23" (584mm)	23 ¾" (603mm)	30" (762mm)	X4FA-2330- N	S S	L W	1530	1591	1652	1744
			36" (914mm)	X4FA-2336- N	S S	L W	1631	1696	1761	1859



X4FA-NSBSSNLW



Features

- Includes non-veneer top, optional full finished back, ¾" (19mm) thick end panels and attachment hardware.
- Non-veneer top with integrated horizontal wireway.
- Wood case and drawer front finish.
- Factory installed Full Back Option adds ¾" (19mm) to the overall lateral file depth.
- Choice of drawer body finish:
  - Standard: Black Miterfold
  - Optional: Wood - English dovetailed Baltic Birch
- File drawer with an integrated file hanging system.
- Two file hanging bars included per file drawer.
- File drawers have full extension slides.
- Drawer pulls options include: Finger, Bar, Linear and Classic.
  - Finger pulls are horizontally routed into MDF; finished to match drawer front.
  - Bar pulls available in powdercoat finishes.
  - Linear and Classic pulls are available in satin nickel finish only.
- One lock standard per lateral file.
- Lock plug is available in black or chrome.
- Lock plug(s) and key(s) are shipped with random numbering unless they are specified "keyed-alike" or "master-keyed".
- Glides provide 2" (51mm) adjustment range.
- Lateral file shipped assembled.

Specification Tips

- 18" (457mm) and 18 ¾" (476mm) deep lateral files for use under 19" (483mm) deep worksurfaces.
- 23" (584mm) and 23 ¾" (604mm) deep lateral files for use under 24" (610mm) deep worksurfaces.
- Separately specified worksurface may be added to Attached Lateral File with Back Option for use as freestanding two-high unit.
- Finger pull option not available with Double-cut Veneer finishes.

To Order, Specify:

1) Product number, including:

❶ File Drawer Option:

- **S** Black Miterfold
- **W** Wood, add **$90** list

❷ Drawer Pull Option:

- **F** Finger
- **B** Bar
- **8** Linear
- **9** Classic

❸ Back Option:

- **N** No Back
- **Y** Finished Wood Back, add **$235** list

2) Wood finish.

3) Trim color for optional Bar Pulls.

4) Trim color for lock plug.

Appendix J

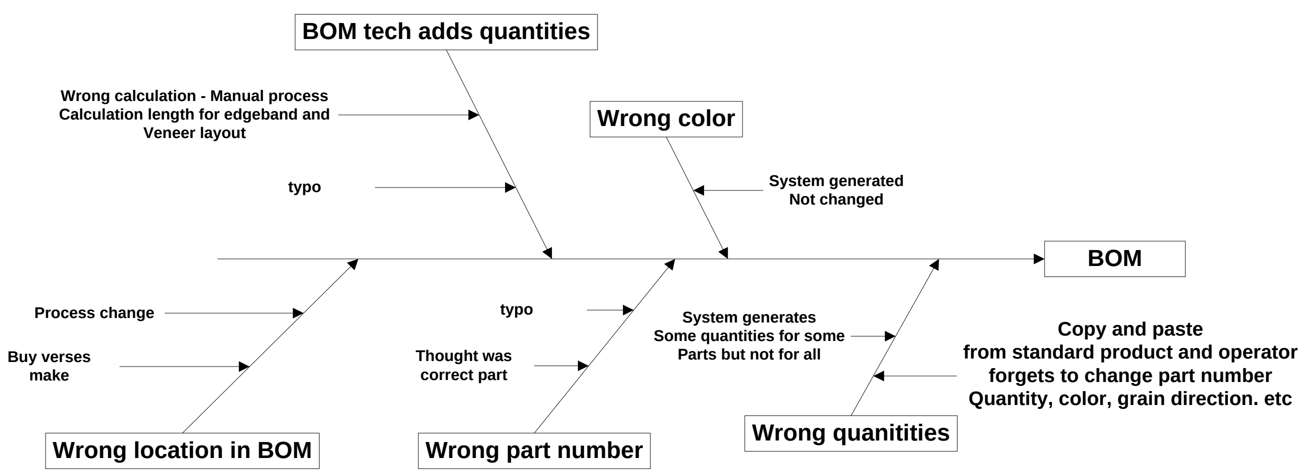
Complexity Definitions for the Custom Products

The complexity scale is based on levels of 1 to 4. A “1” assigned means that there was no bill of materials (BOM) work required. It was designed before in a previously order and already loaded into the system. The order was just being re-ordered. A “2” assigned indicates a simple stretch and pull. This means that a work surface, for example, needed its width, length, or both at different lengths from what was published in the catalog, hence the reference of “stretch and pull.” Complexities of a “1” and “2” were not given any extra lead time in the schedule; they were the same as standard product. A “3” assigned indicates that the base product was changed to eliminate or create new features. A level or score of “3” could also mean a request for Customer’s Own Material (COM), such as wood veneers. In this case, more time was allotted to the lead time, often depending on material availability and manufacturability. A “4” assigned basically signifies a new product all together, which requires 50% more time and effort over the assignment of a “1” or “2”. The lead time for a “4” could be extended as much as twelve weeks (standard product varied from four to six depending on type) due to testing that may be deemed necessary by the design engineer, as well as any materials lead times.

Appendix K

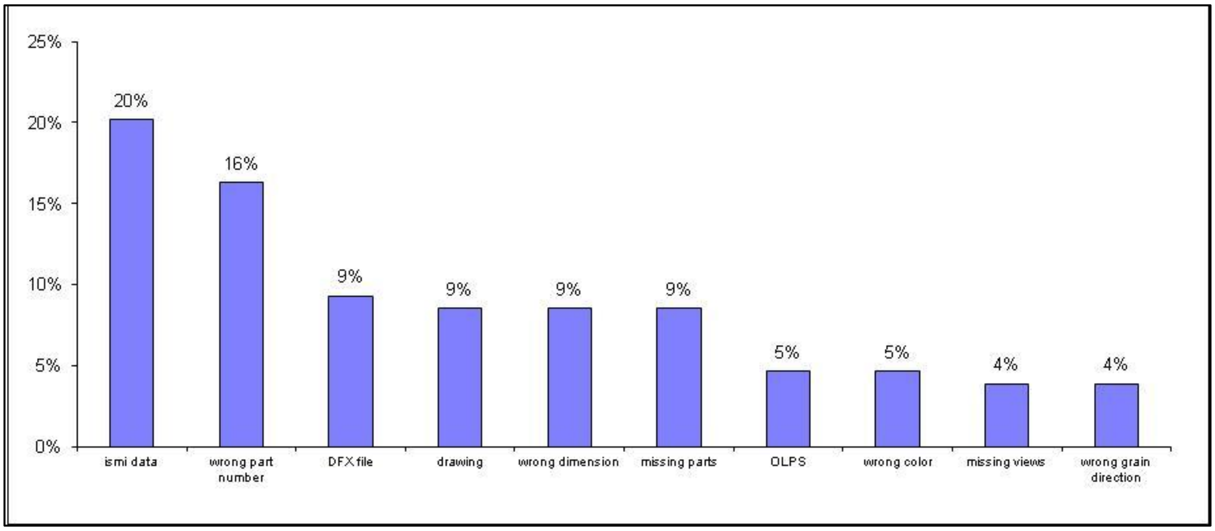
How to create a Fishbone Diagram

The fishbone diagram takes the main effect error, which is a BOM error in this example, represented by the spine of the fish. Main causes for BOM errors such as wrong part quantities, are represented by the lines that feed off the main line, or which represent the ribs off of the spine of the fish. Secondary causes are the lines that feed off the ribs; they represent the breakdown of the main cause and sometimes a root cause, if it is not a root cause, another line is created off the secondary cause line. In the cases of the wrong part quantity, one of causes is due to the copying and pasting of standard product BOM into the ECO to alter the new product. What happens is the designer forgets to change the part quantity reflecting the new product and it creates an error.

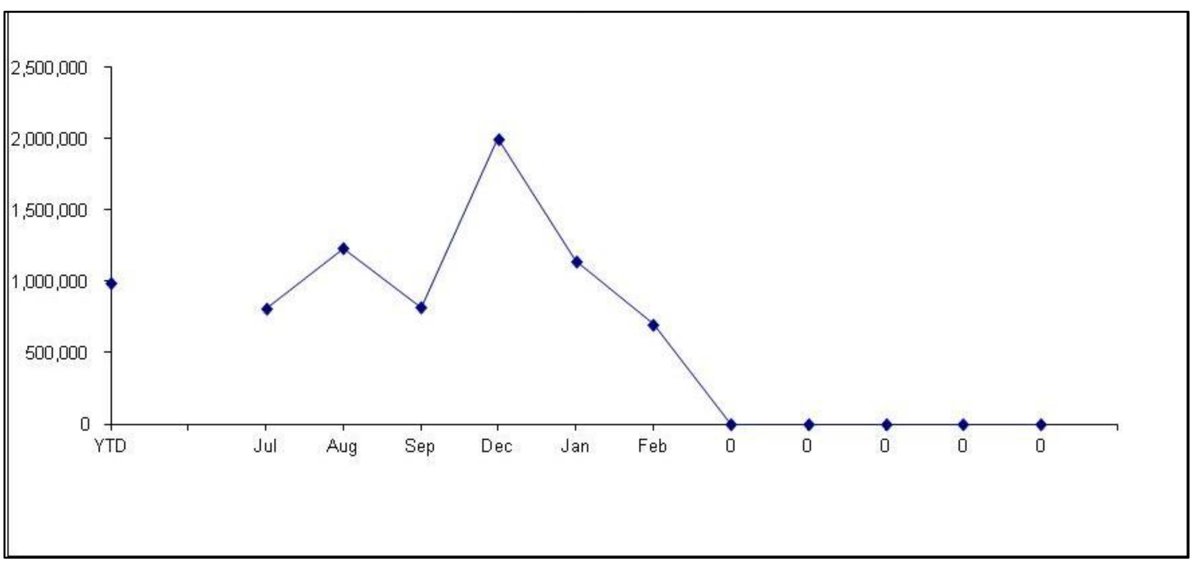


Appendix L

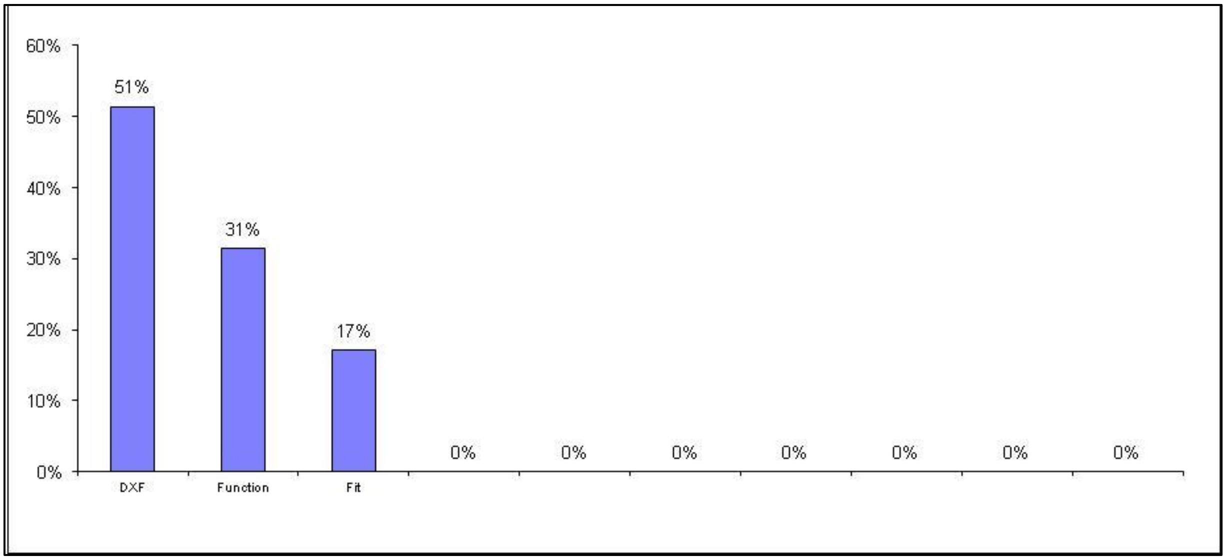
Pareto and Trend Charts of the Error Types



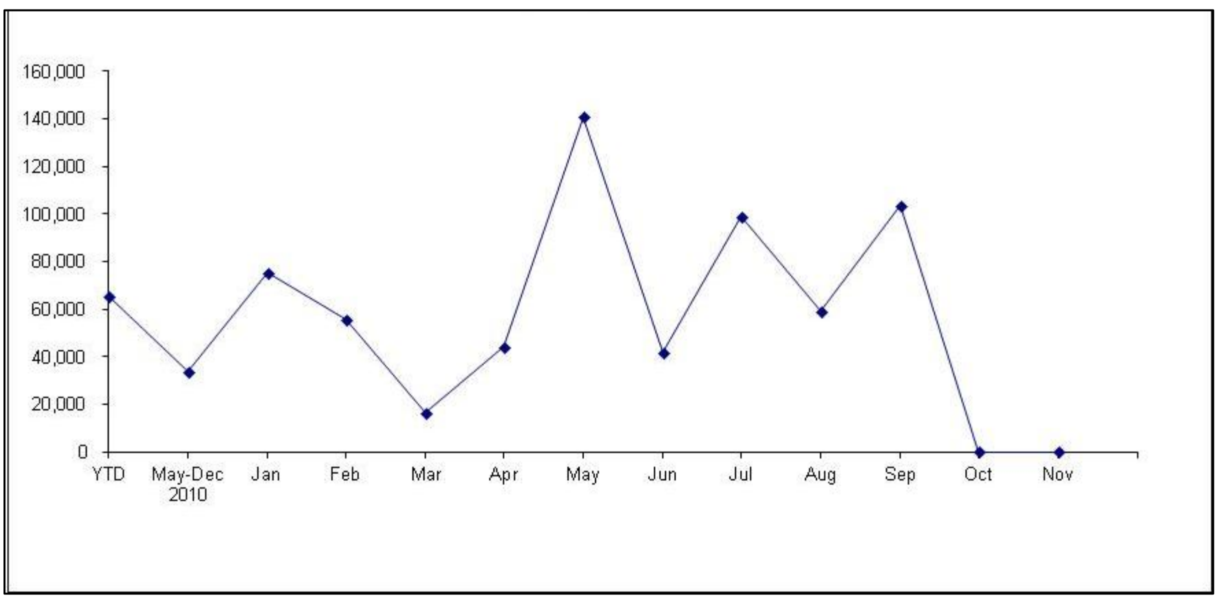
Pareto of Designer Check Sheet Errors 2011



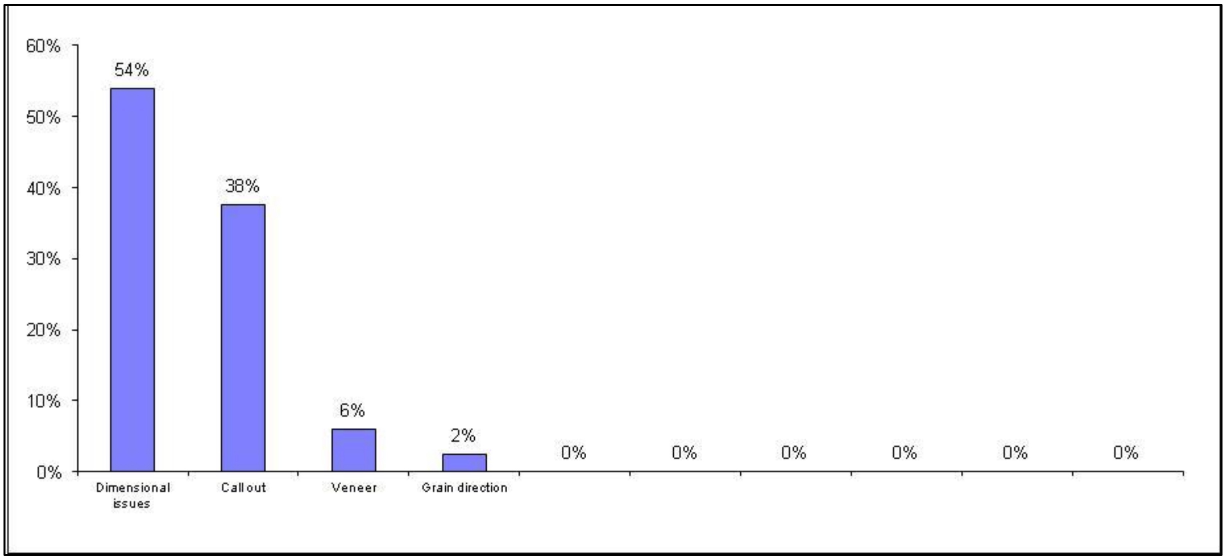
Trend Chart of Designer Check Sheet Errors 2011



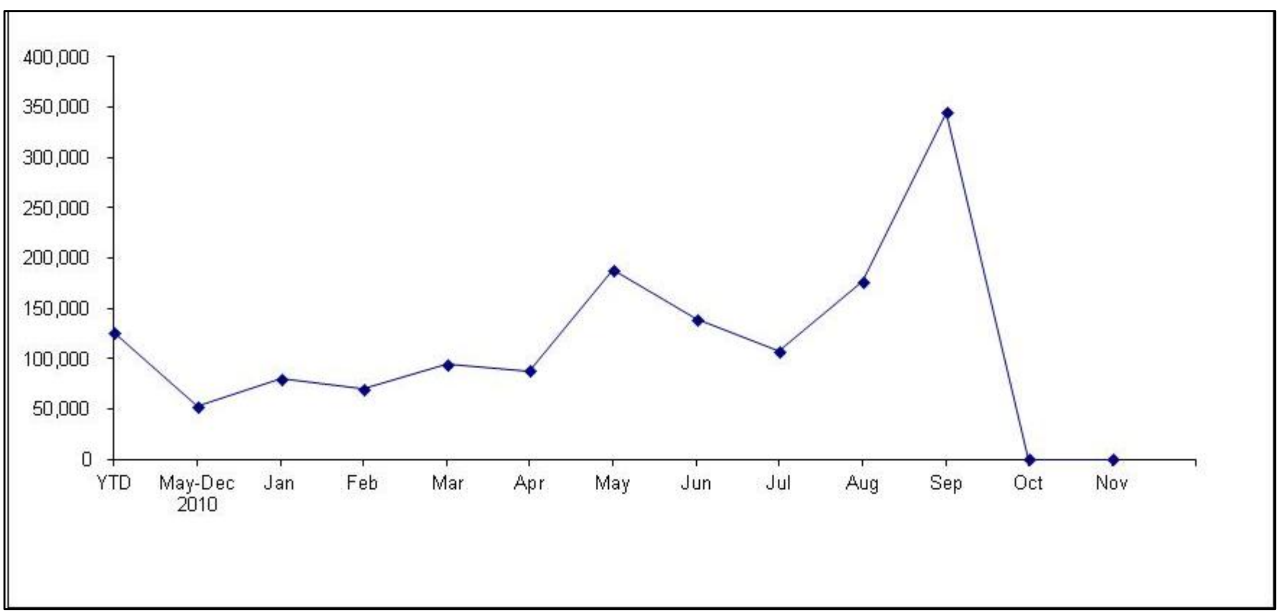
Pareto of Designer Error found at FPY 2011



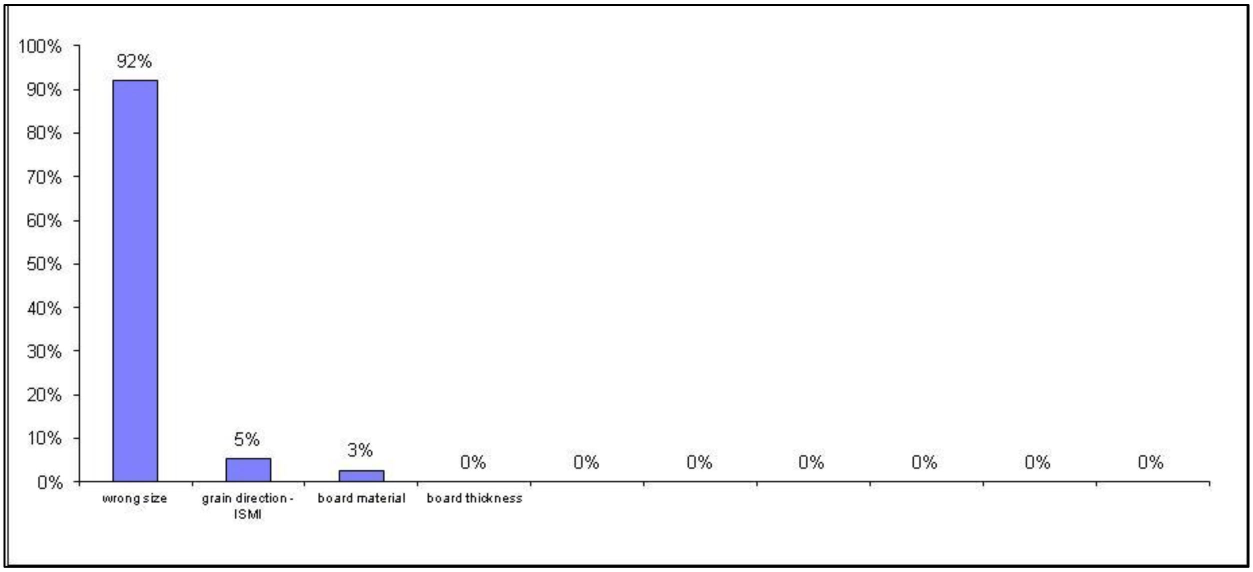
Trend Chart Designer Errors found at FPY 2011



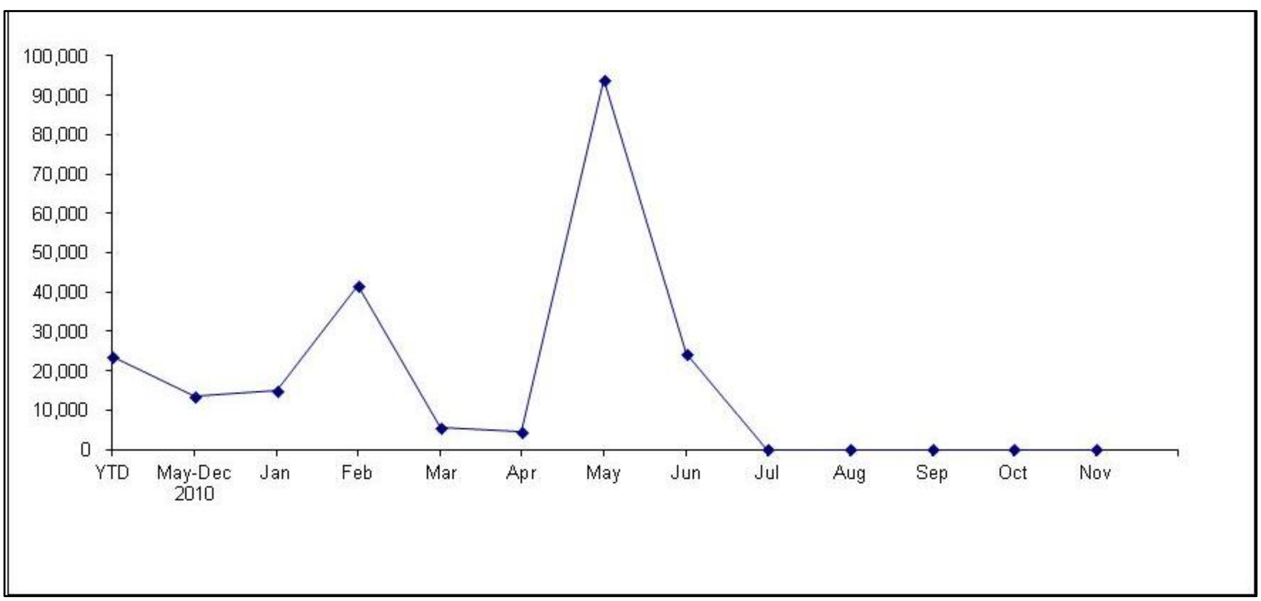
Pareto of Print Errors found at FPY 2011



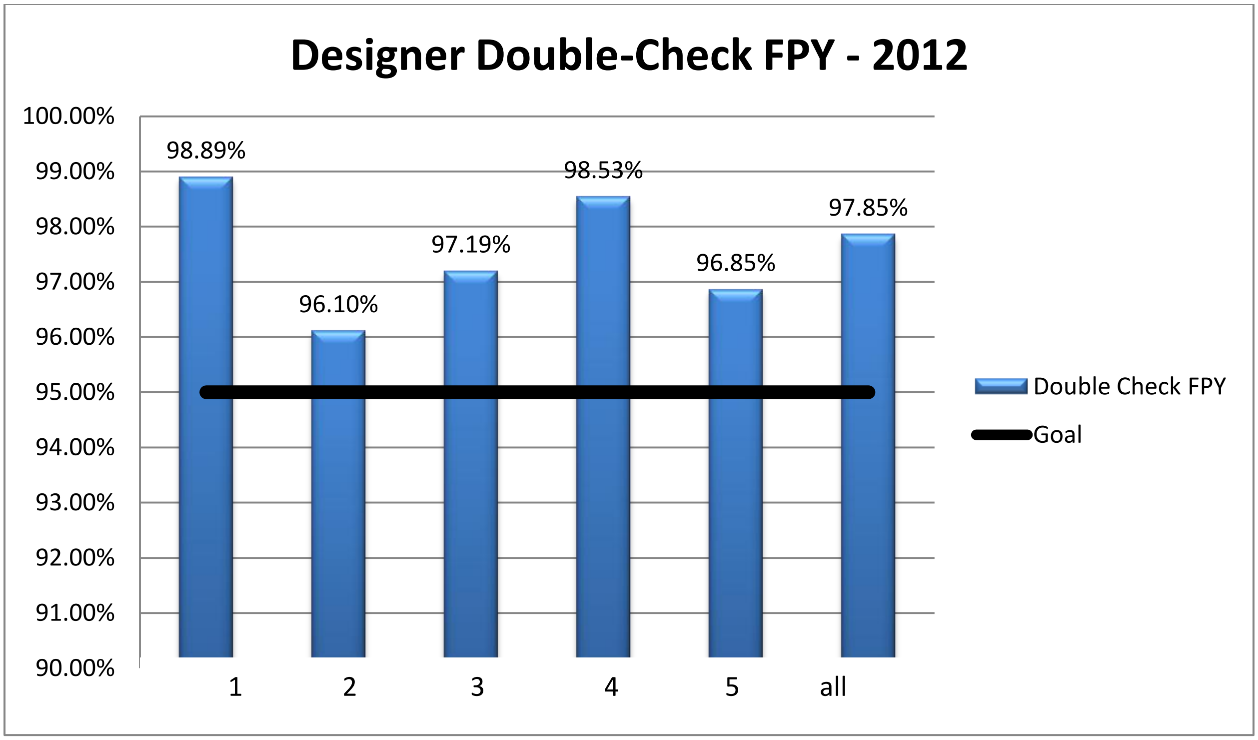
Trend Chart of Print Error found at FPY 2011



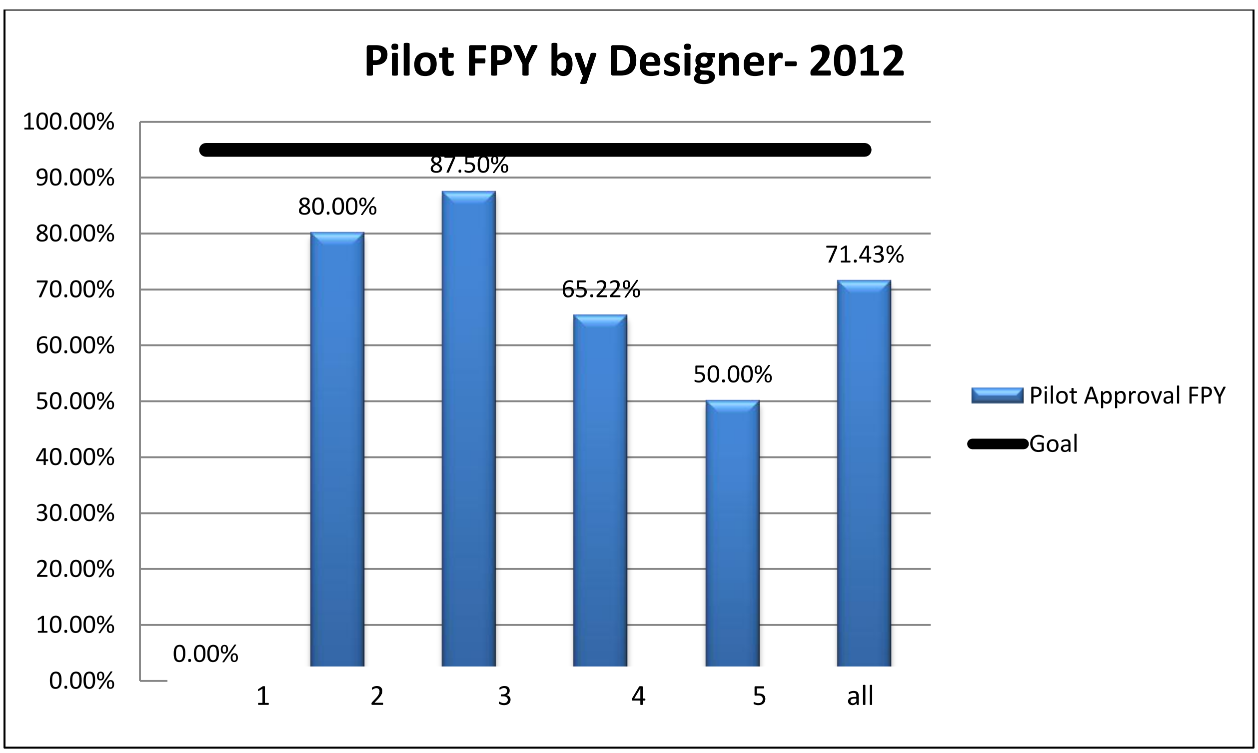
Pareto of ISMI Errors Found at FPY 2011



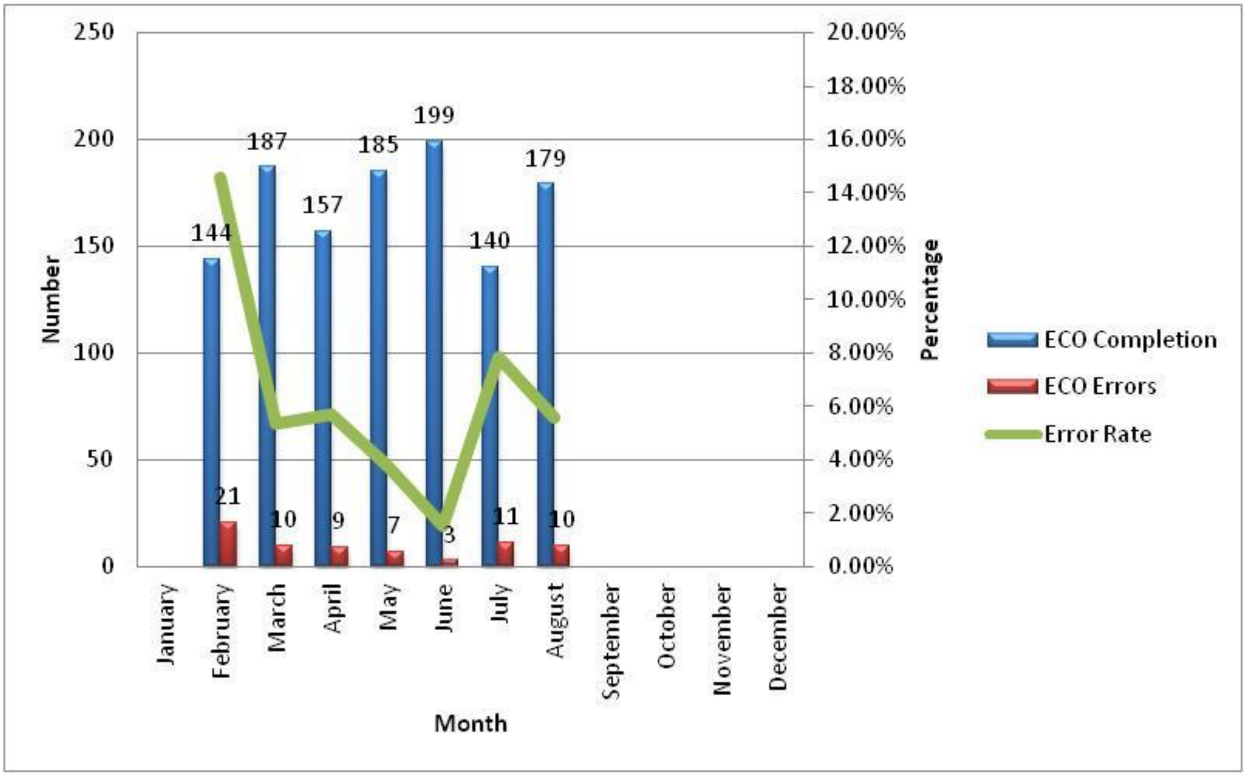
Trend Chart of ISMI Errors Found at FPY 2011



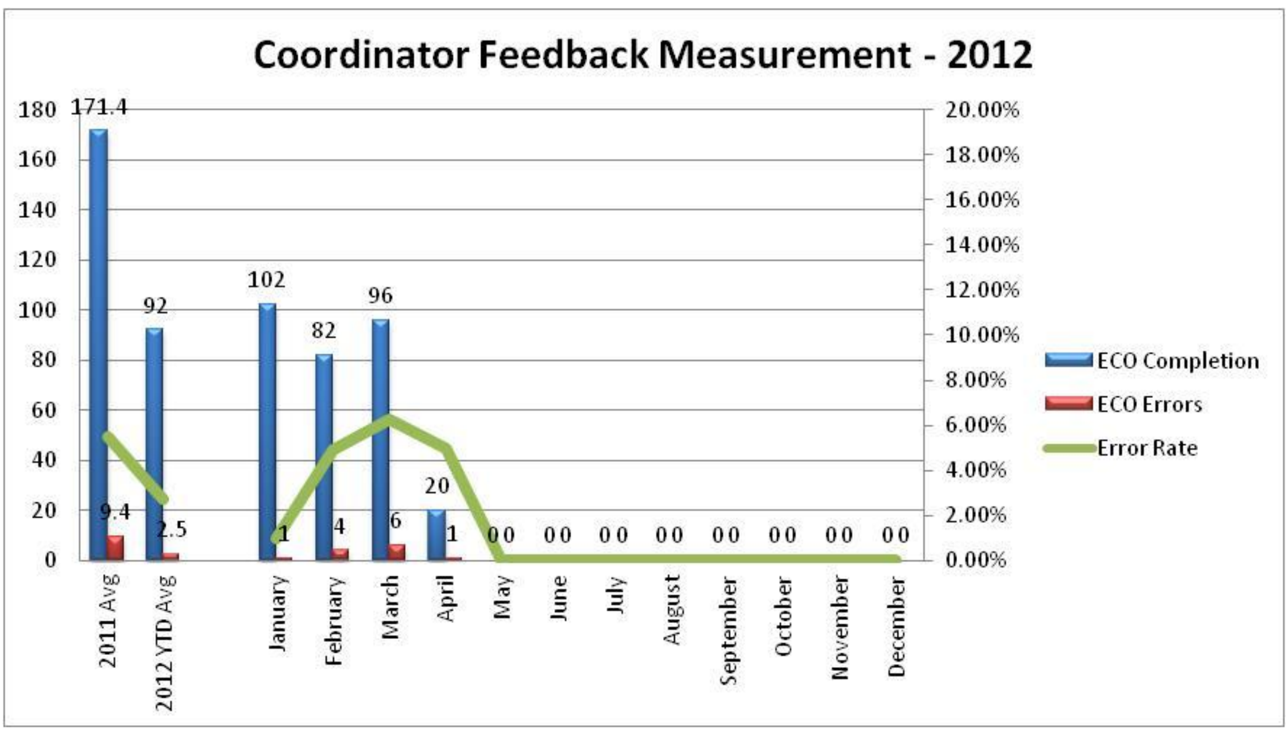
Check Sheet results for 2012 January to March



FPY Results by Designer January to March 2012



Coordinator's Report Based on Designer Check sheet 2011



Coordinator's Report Based on Designer Check sheet 2012
Trend year over year since began in 2011

Appendix M

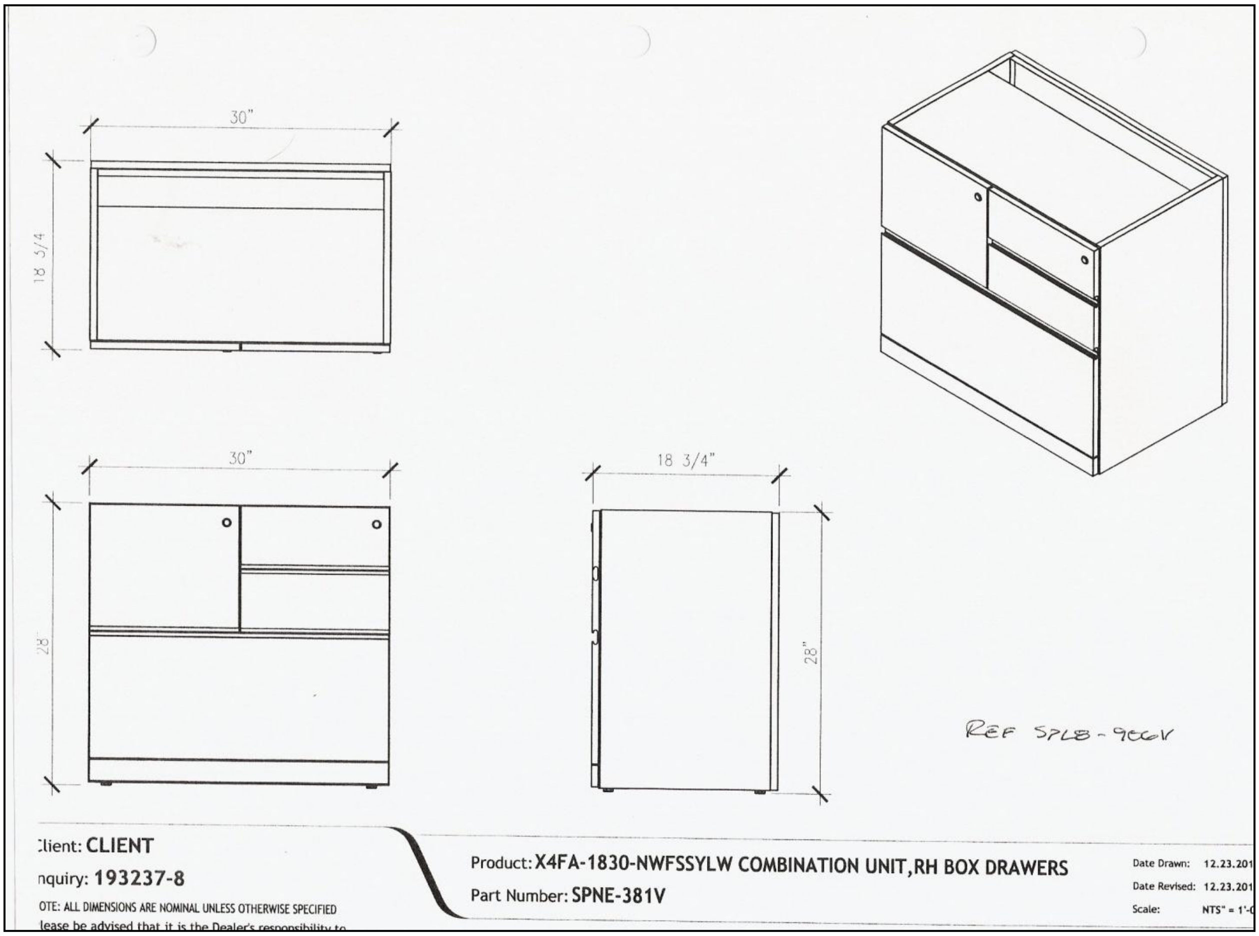
Job Breakdown Structures

JBS are three-column charts that break jobs down into major steps, keypoints – detailed instruction, and the reasons for keypoints (Liker, 2007). The major steps are the events in standard work and placed in the first column of the JBS chart. The keypoints have categories of safety, quality, technique, and cost. If the major step involves a keypoint, such as a quality point, the details are listed in the middle column. The reason for the keypoint, as shown in the last column, is to inform the doer of why the steps must be carried out in the exact manner described in the keypoint or else the keypoint failure may occur.

Job Breakdown Instruction	BPU #	Prepared by:
WC#: Step 2	Part Family: Table	Part #:
WC Name: Designer	Part Name:	Operation #:
Approvals:	Mfg Eng:	Quality:
Work Element **(WHAT to do)**	**Detailed Instruction** **(HOW to do it)**	**Key Learnings** **(WHY you do it that way)**
1.calculate table dimensions for wood layout	1. The table has wood has what edgeing? I - wood edgeband add 10 mm - plastic edgeband - 0 mm - cascade edge - 15 mm - laminate top - add 5 mm - veneer top add 0mm	1. The different edges require second cuts to cut the side of the wood to match the mounting method of the edgeband. If not added , when cut will remove material and table will be too small
2. Run ISMI for	2. Run macro to create cutting path to create wood layout .	2. the proper size board is used so scrap does occur

Appendix N

The AutoCAD Drawing of the Custom Product Requested



Appendix O

Special Causes

1. Dealer forgot to order part and asked to jump to front of the line to expedite product to be completed over the weekend.
2. Dealer specified work surface to be a width of 33” but really needed a 36”-wide standard product.
3. On ECO-721-237, the time recorded on the ECO package print-out was after for the SIMI input was reprinted because the printer was out of paper.
4. ECO725-814 Repeated replacement order for the third time. This time, the custom product’s grain direction was manipulated to match the surface of the surface next to it. The BOM and routing had to change to force the grain placement of the wood in a specific direction requiring specific routings.
5. Fronts are one piece through the system and, depending on how many pairs there are, the routing times vary.
6. Revisions to standard product parts placed holds on all custom products previously designed that contain the same standard part or the base standard part.
7. PDM link has issues pulling in OLPS.
8. The special cause to trend graph on the capacity was the firing of one designer and the hiring of another one in June. The graph identified that the new designer was making error because he was not given proper training, thus increasing the errors. If the department utilized job breakdown sheets, the new designer would have had some training before commencing his new job. The data reinforced the need to implement training regiment and a kaizen was identified to be completed.

Appendix P

Kaizen Events

1. **Planning for a Week-long Kaizen**

   Kaizen events must be planned in advance. They must include the cross functional participants with approval authority and “buy” in from all. The event must be singular in focus in order to be completed in one week.

2. **Identifying the Area of Focus**

   The area of focus must be chosen is to have the best impact and control from participants being able to complete the kaizen. Using an Impact and Control matrix to help prioritize will help identify areas of focus.

3. **Setting Scope**

   The rule for scope is to choose a project that can be accomplished within a single week. Although sometimes it will take longer to feel the total effects of the change the implementation should be limited to a week. Larger projects will therefore need to be pared down into smaller ones to be able to implement. For example, create standard work in one week and implement it in a second event.

4. **Selecting Team Members**

   The team must be cross-functional in nature. It may include managers, engineers, operators, and even office personnel—anyone involved in the project.

5. **Training**

   Kaizen events often require training, since certain team participants may not have been trained on a specific tool that may be used such, as fishbone diagrams or VSMs.

   Knowledge for the Leader (train the trainer and trainer documents)

   There are train the trainer documents to help the leader of the kaizen run the event. There are also forms to fill out to help keep the team on track for time and on target toward the goal.

Appendix Q

Continuous Improvement Cycles

Kaizen events begin the continuous improvement cycle—also referred to as the corrective action feedback loop, if implemented properly. The corrective action feedback loop, or continuous improvement cycle, can involve many steps. TPS uses the A4, General Motors the 8D. Others may use the 5 phase, and still others six sigma's DMAIC. Each methodology defines the problem, contains it, and measures it, n analysis of the problem, then select and implement a solution. Lastly, it verifies that the solution worked and remains in control by some measurement method. The problems and solutions serve as feedback into the process so that everyone learns not only what caused the problem but also the solution, so that the problem does not occur again, in this way closing the cycle or loop. Figure 27 on the left depicts a six-step approach to the closed-loop continuous improvement cycle. The right side of the figure shows the plan-do-check-act circle often referenced in lean text. These are used in conjunction with the lean tools and methods used in this work.

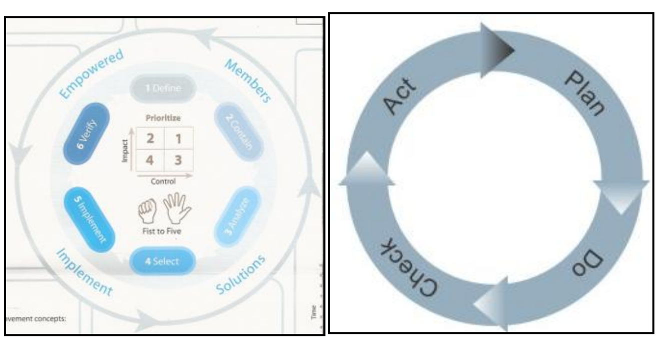


Figure 27: Closed-loop Improvement Cycles

Right: Six Steps. Left: Plan-Do-Check-Act

Glossary

Number	Word	Definition
1	Backlog	An accumulation, especially of unfinished work or unfilled orders
2	Comstar	Computer database for inputting orders and system that manages the Bill of materials
3	Cycle Time	The time the tasks begins until it is completed, does not include wait time.
4	Data Box	Goes under other icons that have significant information or data required for analyzing and observing the system
5	DNet	A proprietary software suite of network protocols created by DIAB, originally deployed on their Data-board products
6	First Pass Yield	It is defined as the number of good units coming out of a process, divided by the number of units going into that process over a specified period of time. Good meaning free of defects units with no rework are to be counted as good product coming out of an individual process.
7	Kaizen Burst	Used to highlight improvement needs and to plan kaizen workshops at specific processes that are critical to achieving the Future State Map of the value stream
8	Master Scheduler	A job that enters orders into the (or "a," depending) system that assigns priorities to jobs submitted for execution
9	Price	It is the monetary amount an item cost to purchase
10	Process Box	A process, operation, department, or work center that other value stream families share
11	Special Cause	A special cause is a unique cause that is not repeated

12	Standard Work	A simple written description of the safest, highest-quality, and most efficient way known to perform a particular process or task
13	System Product	Furniture made of metal, plastics, and some wood that makes up the file cabinets, chairs, desks, and/or overhead compartments of cubical office furniture
14	Takt	Time available per shift (day) divided by the customer demand per shift (day)
15	Wood Product	Furniture made of 90% or more wood and such the structures are made of wood like a desk, shelves, cabinets to name a few
16	Value	It is what the customer is buying or willing pay for when purchasing something when market determines the price
17	VSM	Provides optimal value to the customer through a complete value creation process with minimum waste in the process

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