Value Stream Mapping for Lean Manufacturing Implementation

Major Qualifying Project Report
submitted to the Faculty of

WORCESTER POLYTECHNIC INSTITUTE (WPI)
and
CENTRAL INDUSTRIAL SUPPLY (CIS)

in partial fulfillment of the requirements for the
Degree of Bachelor of Science

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August 31, 2007

Abstract

Central Industrial Supply (CIS) in Wuxi, China is a manufacturing company that produces a variety of electromechanical components. The lead time for the 9G product is 6 to 7 days from when it leaves the first factory until it is ready to be shipped. Our project focuses on creating current and future state value stream maps which, when implemented, will decrease the current lead time by 50%, as well as provide recommendations to improve current operations within the company.

Acknowledgements

We would like to thank Central Industrial Supply (CIS) for sponsoring this project and hosting us in Wuxi. We would especially like to thank Larry Zhong and Chaozhong Dai for their continuous assistance throughout this project.

We would also like to thank Huazhong University of Science & Technology (HUST) for their hospitality; we enjoyed our short stay on campus. Finally we would like to thank Professor Rong for setting up the HUST project center in China and his advice throughout the project.

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1.Introduction

With manufacturing becoming a more and more competitive market, companies globally strive to increase their efficiency. Increasing labor costs in many industrialized countries, as well as reducing and controlling operating costs, are just a few reasons companies choose to move or outsource their operations. Typically a majority of companies outsource to countries where wages are low and production costs are lower. To reduce cost and remain competitive with manufacturers abroad, companies use a variety of different methods. One of the main methods is called “lean manufacturing.” The main principle of lean manufacturing is to reduce waste in an operation, such as long lead times, defects and material waste. In order to visually display where waste occurs in the process, a value stream map (VSM) is drawn. VSMs are often used to assess current manufacturing processes as well as create ideal, future state processes. With the manufacturing field escalating and spreading more widely across the globe, it is important for companies to adapt to the increasing and evolving business strategies.

For this project we worked with the manufacturing company, Central Industrial Supply (CIS), in Wuxi, China. We focused on the company’s main product, the“9G” slides that are used in rack mounts for servers. Currently the production for the slide is broken up into four steps which include roll forming, stamping, plating and final assembly. The roll forming and stamping operations are completed in one factory, while final assembly and shipping are completed in another CIS factory, located a few kilometers away. Plating is completed by an external company due to the lack of an appropriate license to perform plating near the current CIS facilities. Parts are shuttled between the different factories usually twice per day; at the beginning and end of the working day. The company is operating under the “built to order” strategy of lean manufacturing, meaning it does not keep a large inventory of finished parts and only creates a certain number of parts depending on customer demand.

The CIS Wuxi plant produces 2400 units per day, and 50,000 units per month. Within their manufacturing process, they have an average total current lead time, which is the total time required to complete one unit of product or service, of 6-7 days. The lead time, referred to here, spans from when the slides leave factory 4 to when the final product is boxed. Our project identified the plating operation, which involves the external plating contractor, as the biggest portion of the current lead time. The plater is supposed to operate under the “minimum/maximum” principle, meaning that a certain level of stock is maintained and when parts are used or removed they are supposed to be replaced. With the initial project research and further investigation, the team found out that this principle was not always implemented.

Value stream mapping has so far not been used by CIS as a tool for operational improvements. The team efforts were the first in that direction.
Our primary project goal was to reduce the current lead time by at least 50%. In order to achieve that goal, the team first had to document the current state of the production process. With the creation of an initial and final state VSM, the group was able to draw conclusions based on the research and data they accumulated, and they were able to achieve the primary goal of the project. The second project goal was operational improvements in the production facilities. The team completed onsite observations and time studies in both factories 4 and 6. After in-depth operational analysis, the team gave recommendations to balance the production lines and optimize delivery times. Furthermore, the team gave suggestions on 5S concepts to standardize the work and material flow. We achieved these operational improvements through the optimization of delivery times and inventory levels and also reduced the total cycle time.

2. Literature Review

This section of the report provides a brief background on the topics we researched in order to complete this project. Lean manufacturing, value stream mapping and information about the sponsoring company were relevant information we needed to consider before we began work on the project.

2.1 Lean Manufacturing

Starting in the early 1900's Henry Ford "married consistently interchangeable parts with standard work and moved conveyance to create what he called flow production." Not soon after WWI the Toyota Production System, TPS, introduced lean manufacturing concepts into the manufacturing industry ("A Brief History of Lean" 2007).

Lean Manufacturing has increasingly been applied by leading manufacturing companies throughout the world. It has proven to have many positive outcomes which include such concepts as reduced cycle time, decreased cost, reduction of defects and waste. Lean manufacturing aims to achieve the same output with less input; such as less time, less space, less human effort, less machinery, less material and less cost. To better understand lean manufacturing, one first needs to understand the basic principles that guide it. Some major lean manufacturing principles include: recognizing wastes, having standard processes, having a continuous flow, pull-production, quality at the source and maintaining continuous improvement.

According to the TPS, there are seven original wastes known as "muda," which means "waste" in Japanese. In order to create a lean working environment, these wastes need to be identified and depleted. The first muda is overproduction, which is producing more than necessary, or more than is needed by the costumer. The second muda is the presence of defects. Defects in products lead to more costs and waste of production time, as well as the effort involved in inspecting and fixing defects. The third waste is inventory. Inventory could lead to added storage costs as well as higher defect rates. Even if there is no "inventory fee," large inventories cost company money because it increases their operating costs. The fourth muda is transportation, which could be transporting goods from one factory to another. Transportation, strictly seen, is a non-value added activity, so companies strive to lower transportation distances. The fifth muda, waiting, is very important to lean manufacturing because this is one of the main wastes that production companies want to minimize. Waiting causes waste of time and money. The sixth waste is over processing. Over processing is unintentionally doing more processing work than the customer requires, which can lead to higher costs by using more resources than needed. The final waste is unnecessary motion. Walking from operation to operation or around the factory floor when not necessary, slows down the workers and overall slows down the flow of production (Mekong, 2004). Detecting and diminishing these wastes within the production process will overall help to create a lean working environment within a company.

2.1.1 Value Stream Mapping

Value stream mapping, a lean manufacturing tool, which originated from the TPS, is known as "material and information flow mapping." This mapping tool uses the techniques of lean manufacturing to analyze and evaluate certain work processes in a manufacturing operation. This tool is used primarily to identify, demonstrate and decrease waste, as well as create flow in the manufacturing process. VSMs can be created merely using paper and pencil; however more advanced maps are created using Microsoft Visio as well as Microsoft Excel. Below you can see an example of a very basic VSM created with Microsoft Visio.

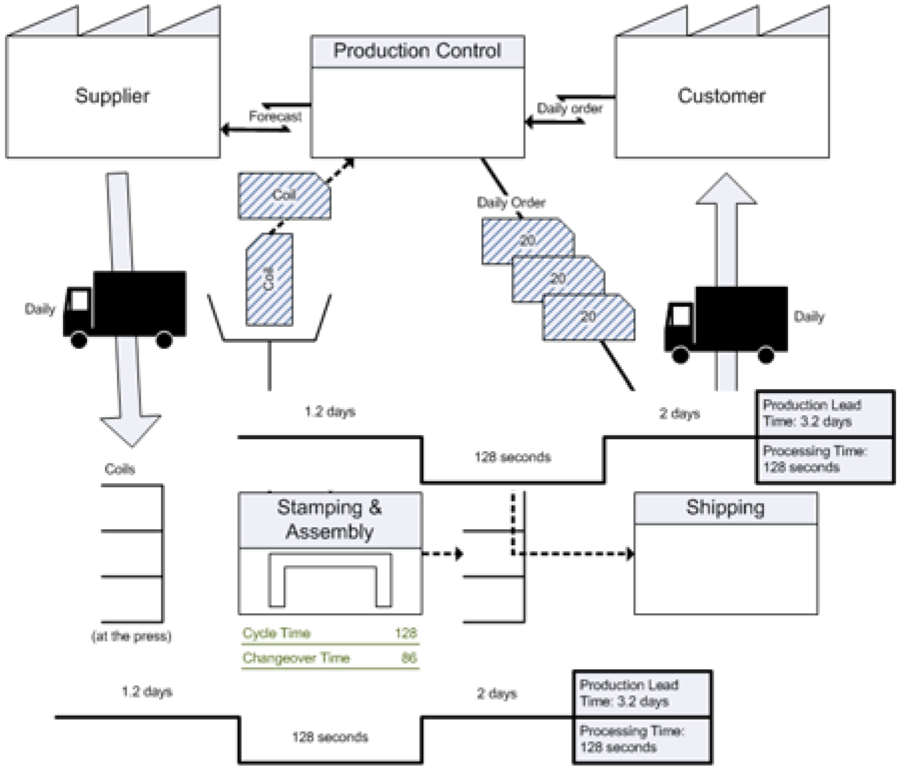


Figure 1: Sample Value Stream Map

The creation of a VSM is divided into five basic steps: 1) Identify the product. 2) Create a current VSM. 3) Evaluate the current map, identify problem areas. 4) Create a future state VSM. 5) Implement the final plan.

The first step, identifying the product, consists of choosing which specific product the VSM will focus on. After the product used has been chosen, an initial VSM of the current process is created. Following the completion of the current map, the team evaluates the process and the steps involved. All this information is then compiled on a map and analysis is performed. On a typical VSM every step of the process is included. For each step, parameters could include cycle time, TAKT time, work in progress (WIP), set up time, down time, number of workers, and scrap rate. A VSM identifies where value is added in the manufacturing process. It will also show all other steps where there is non-added value. After analyzing and evaluating the current process of the product, the problem areas can be identified. Once you have changed the current process to minimize problem areas completely, you can create a final state VSM. The last step of the value stream mapping process is to implement the new ideas, which will in turn create a more efficient lean manufacturing process (Hines).

2.1.2 Arena Simulation Software

To aid the decision making process in today's business world, companies increasingly use simulation software to simulate possible future states. For this project the team used the educational version of Arena, simulation software made by Rockwell Automation.

The team used this software to model and recreate certain parts of the manufacturing process. We entered data such as the cycle time and machine parameters for each operation.

A model made by Arena is based on modules. All information required to simulate a process is stored in modules (Figure 2).

For example, to model the chassis member line, all the appropriate modules are dragged to the simulation window. The production line starts with the "create module" and ends with the "dispose module." In between there are the "process modules."

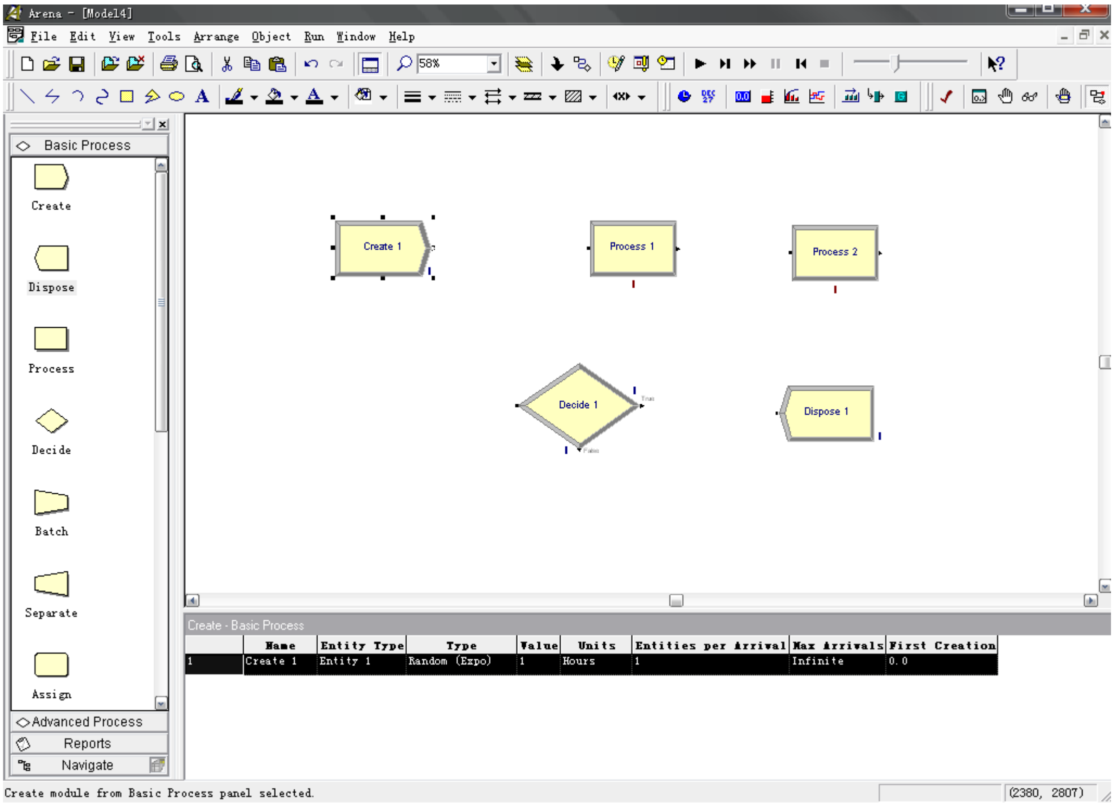


Figure 2 - Initial Arena Setup

Once the basic parameters have been set, the actual process line can be modeled (Figure 3).

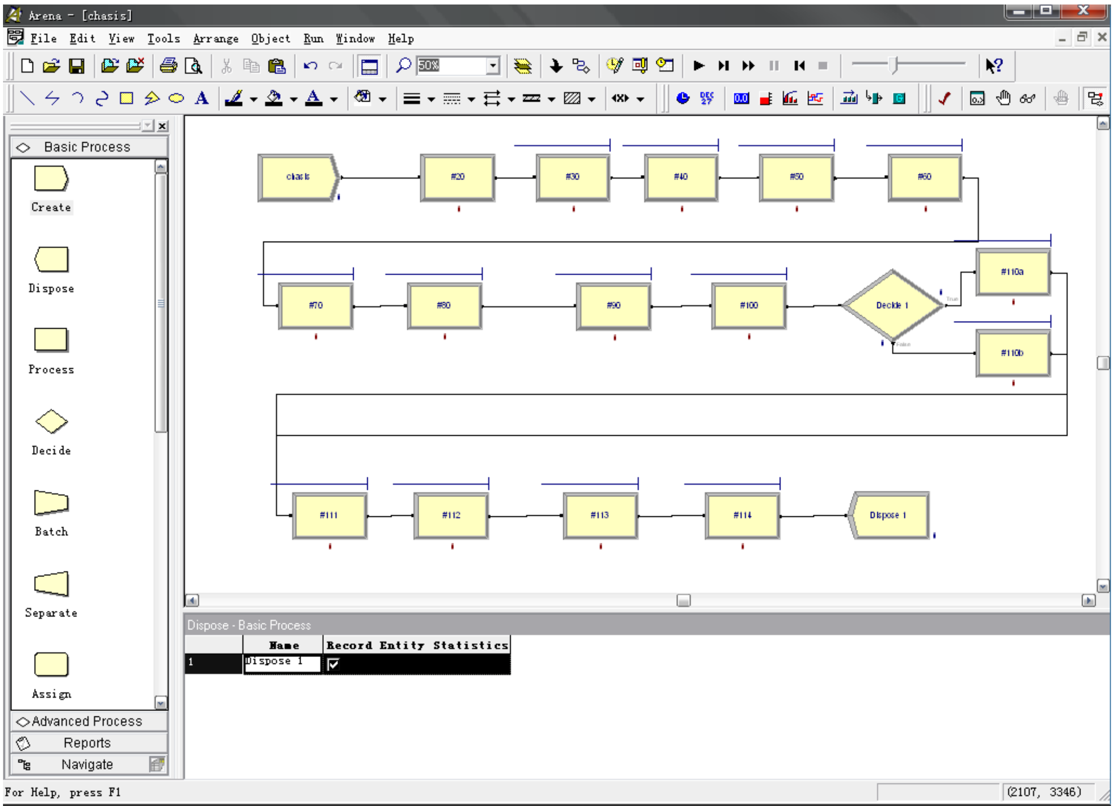


Figure 3 - Chassis Member Line

Then input the data (Figure 4) collected from the production line. Double-click the modules in the Model Window flowchart view or input directly from the Model Window spreadsheet view.

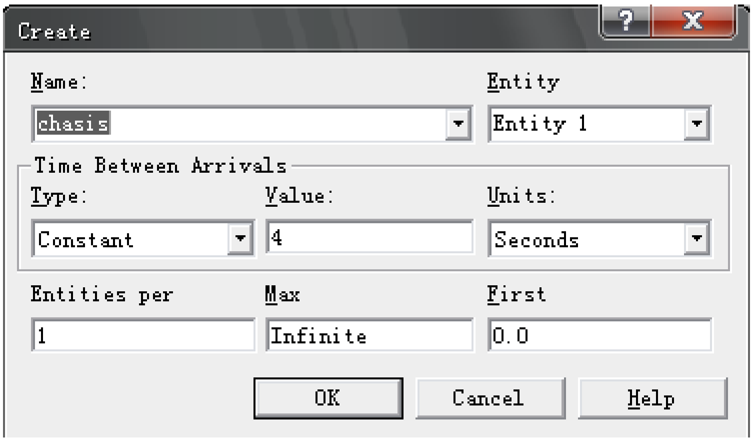


Figure 4 - Input Collected Data

Now you can run the model. With the tool bar, we can control the simulation speed. At last, Arena will give a report of the simulation as seen in figure 5 below.

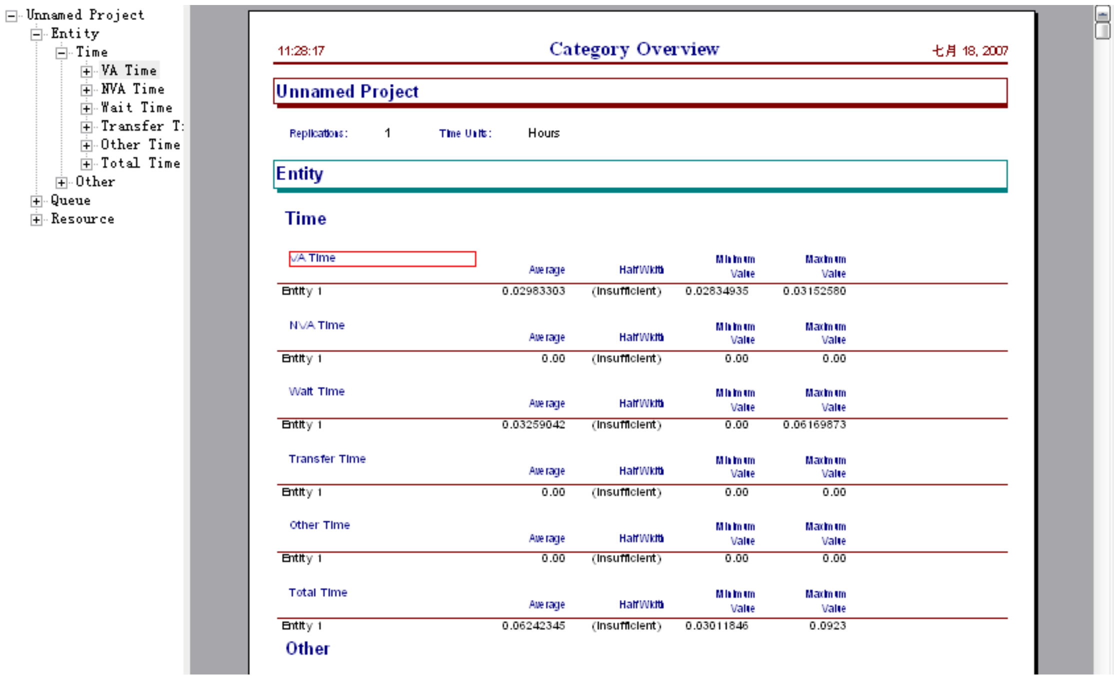


Figure 5 - Sample Production Report Generated by Arena

With this production report the user is now able to analyze the existing or future production states.

2.2 Project Background

In this chapter we will discuss relevant background information for our project. First we will briefly describe our sponsoring company, Central Industrial Supply. Then we will provide information about the product we worked with. Finally, we will dicuss the manufacturing process and the factory layout.

2.2.1 Central Industrial Supply

Central Industrial Supply (CIS) is an international company with design engineering, project management, and manufacturing excellence in various world regions. As you can see from the map below, the CIS company spans from Grand Prairie, TX all the way across the globe to Wuxi, China. There are five regional branches, two of them within the United States of America, one in Europe and two in Asia.

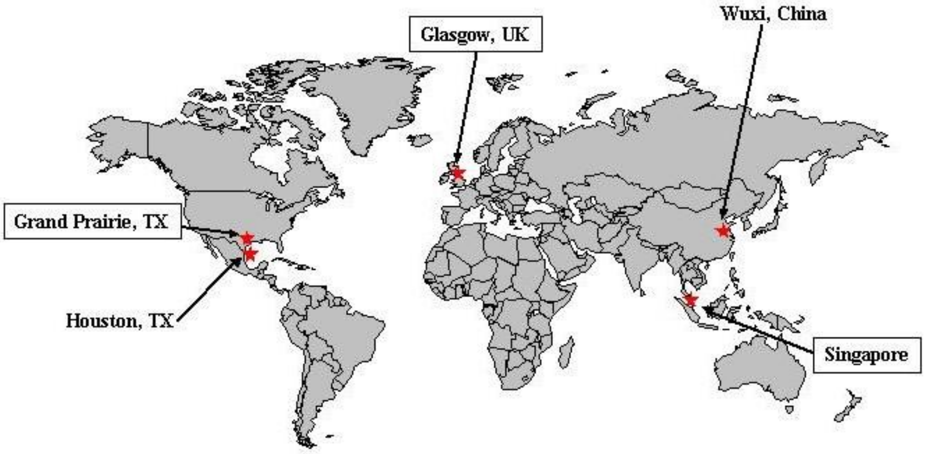


Figure 6: Map of CIS Locations

It was founded in Grand Prairie, TX in 1955. In its early days, it supplied small mechanical components and tooling solely for the North American market. In 1996, with the capability expansion it established the Asia-Pacific CIS Pte. LTD (APCIS) in Singapore, providing logistics services such as material management and assembly for the Pacific Rim market. In 1998, CIS Grand Prairie, TX achieved ISO registration. After that, different branches in worldwide regions were set up and achieved their

ISO registrations. By 2003, CIS Houston, TX, APCIS Singapore, APCIS Wuxi, China and CIS Grand Prairie had achieved an improved level of ISO registration which includes engineering certification in addition to manufacturing certification. Over the past 52 years, it has been developing new products and services to meet the demands of ever-changing market. This makes it able to change from a small mechanical component supplier to a global manufacturer (http://www.cis-inc.net/).

Our team is working at the CIS branch located in Wuxi, China. Before 2000, CIS Wuxi had used other suppliers to provide them with the slides. However, in order to become a more competitive business, they decided they needed to produce the slides within their own facilities. CIS Wuxi is located in two factory locations, one being factory 4, F4 (roll forming and stamping), and the other being factory 6, F6 (final assembly and shipping). The process which takes place between stamping of the metal and final assembly of the product, is the electroplating process. This major production step is conducted by an external plating contractor located approximately 15 minutes away from the CIS Wuxi factories. The reason CIS does not perform the plating on company grounds, is due to the fact that there exist license agreements and water waste issues that will not permit this. Nonetheless, in the future, CIS hopes to incorporate plating along with the other two processes in house.

In 2001, CIS Wuxi manufactured their first slide. Since then, they have been producing many different types of slides and other components every day. Their main product within the Wuxi factory is the 9G slide.

2.2.2 Product (9G)

Our project focuses on the slide design produced by CIS Wuxi known as the 9G rack mounting device. 9G stands for “ninth generation,” which means this is the ninth generation of this specific slide product. An image of this product is shown below.

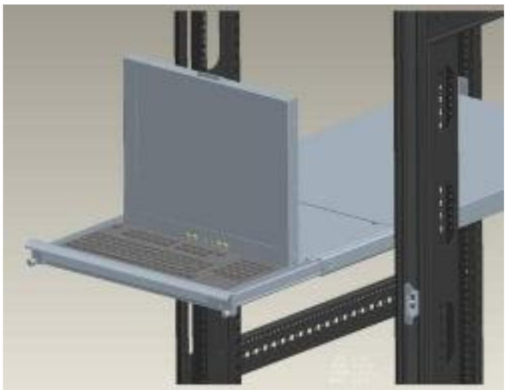


Figure 7: Rack Mounting Device Produced by CIS

These slides are used in server rack mounts. They hold the actual server, and are able to slide the server either forward or backward. The finished kit, which is sent to the distributor from the Wuxi plant, includes a rack mounting device composed of two slides, one for the left and the right, and a cable mounting arm (CMA). The 9G was first introduced in April 2006, and is currently the major selling product of the CIS Wuxi plant, with one of the main costumers for this device being Dell Computer Company.

These slide devices are originally produced as three individual pieces, as you may see in the figure 8 below. The piece that connects to the rack mount is the "cabinet member;" the piece that connects to the console or server is known as the "chassis member;" and the piece that connects these two members together is known as the "intermediate member."

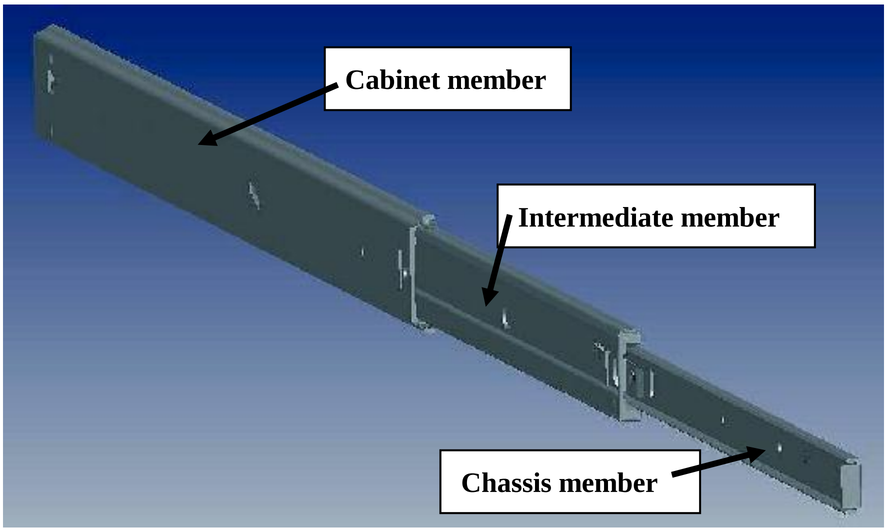


Figure 8: Product

CIS has been producing the 9G slide for over a year now; however they would like to improve the current production process. Our project's goal was to create a VSM which will help CIS reduce the current lead time by 50% and altogether create a more efficient work flow. In addition to reducing lead time, we also developed improvements for their current operations.

2.2.3 Factory Layout

Upon our arrival to the CIS Wuxi plant, we toured F4 and F6. In order to familiarize ourselves with the working area, our sponsor directed us to the factory's floor area where production occurs. When touring the plant directly, we were introduced to employees who worked with us over the course of seven weeks. We also familiarized ourselves with machines and assembly lines.

F4 performs the roll forming and stamping procedures. This factory is currently managed by operation manager Chaozhong Dai, and floor manager Zhihao Li. Each member has a specific production line in F4. Within this work area, there is one roll forming machine for each of the three members. These machines feed the raw material, rolls of thin steel, into a machine, which then forms the metal into its specific shape and cuts out a certain portion.

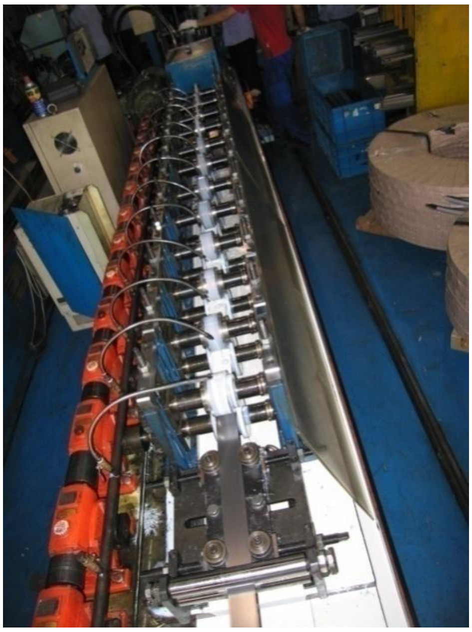


Figure 9: Roll Forming Process

Figure 10 - Stamping

The stamping process in F4, (Figure 9), consists of a variety of stamping machines, which differ with each member's production line. The stamping process (Figure 10) includes such operations as lettering, stamping, chamfering and deburring. The intermediate member contains the greatest number of stamping machines, while the cabinet member contains the least.

F6 is where the final product is assembled, packed and shipped out to the distributor. In this factory, Larry Zhong is the operation manager and Hua Li is the floor manager. Within the assembly process there are different machines used to join the plated slide members with purchased parts. There are three slightly different models in the 9G product line. They are categorized as the London, Berlin and Montreal slides. In F6, we focused our concentration on the London assembly line. As seen from the floor layout of F6 below, figure 11, the purchased parts are delivered to the receiving area, and then moved to inventory and from there to production. Once a product is boxed, it is moved to finished goods where it is shipped out.

Ultimately understanding the layout and flow of operations made it easier to understand where the problem areas are located and how they can be fixed.

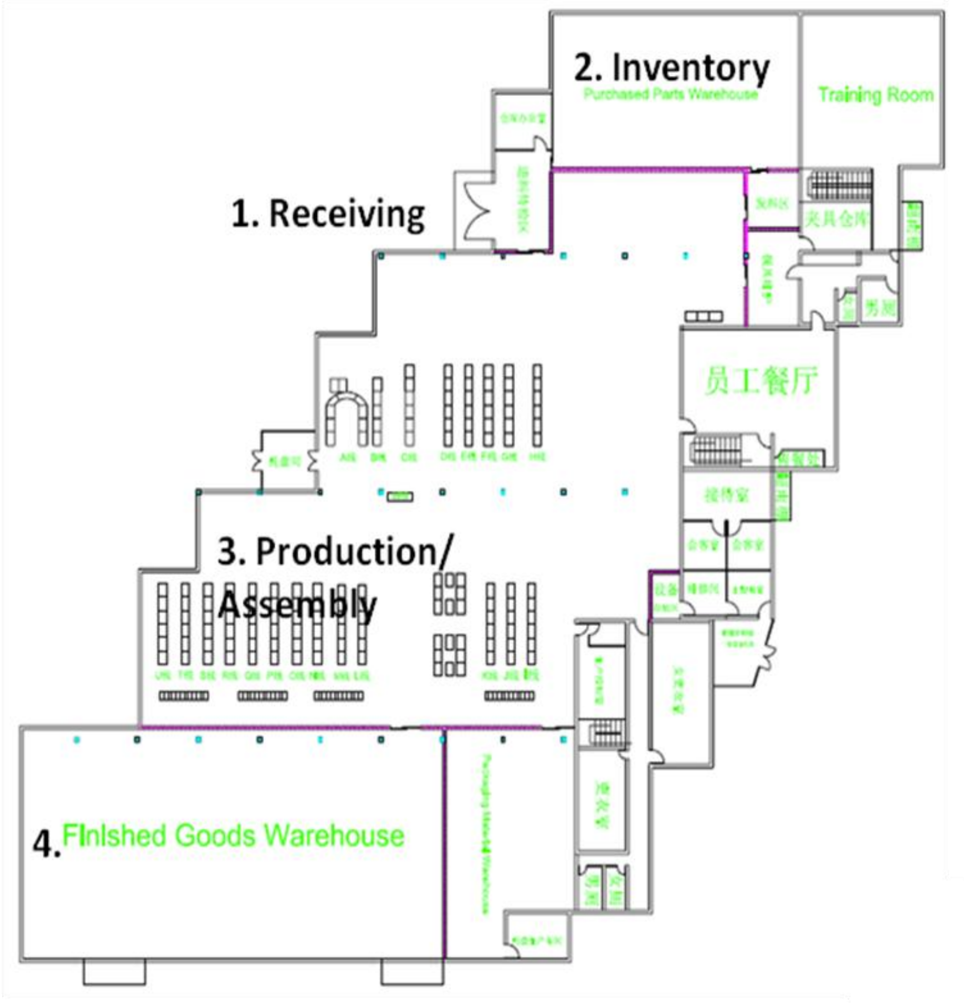


Figure 11: F6 Factory Layout

The topics covered in our background research provided us with methods that are used in lean manufacturing, more specifically value stream mapping. Currently CIS does not use value stream mapping as an operational analysis tool. The WPI/HUST efforts to value stream map a part of the CIS Wuxi operations, the Qualslide (9G) product line, was the first attempt at using this approach. This background research helped us to better understand the project's problem and made it possible for us to achieve our goal.

3.Methodology

The biggest problem for CIS daily operations was long lead times. In order to improve these times, the team set up several project goals.

One of the main goals of our project was to create a future state VSM that illustrated the ideal material and information flow for the CIS Wuxi plant. With the creation and implementation of our VSM, CIS's current lead time should be reduced by 50%.

Through the course of this project we have completed the following objectives: Please refer to figure 12 below.

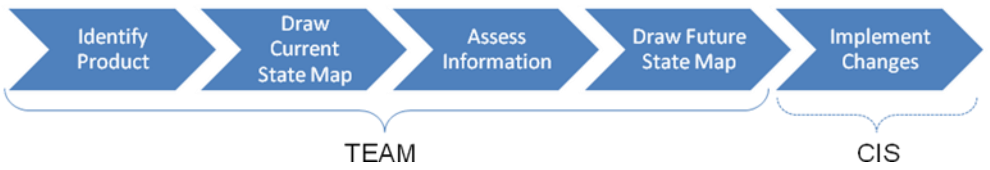


Figure 12 - Project Objectives

- Collected data
- Created a current state VSM
- Created Arena Simulation
- Analyzed the current state VSM and arena software
- Identified non-value added time that increases the lead time
- Created short term and long term future state maps

In order to accomplish these objectives we applied the following strategies:

- Obtained information from various employees
- Conducted time studies
- Observed processes during different times of the day, on different days of the week
- We used Microsoft Visio software to create current and future state VSMs
- We used Rockwell's Arena software to simulate current processes

3.1 Collecting Relevant Data

An essential part in creating the VSMs for the 9G process was to obtain existing data. There were a few ways in which we gained information. The first, we acquired data directly from the company. To do this we talked with the operation managers of each plant as well as the floor managers. We met with the managers and remained in contact through e-mail. The operation managers, Larry Zhong and Chaozhong Dai, for the two factories F6 and F4, respectively, provided us with production data as well as quality data. When we visited the production lines, it allowed our team to record observations as well as conduct time studies on each specific line. We split our team into 3 groups of two people, in which each group recorded information on the three individual members: chassis, intermediate and cabinet.

3.1.1 Interviews with CIS

We obtained a large amount of information when conducting our initial research within the factory. Larry Zhong and Chaozhong Dai, the two operation mangers as mentioned before, provided us with such information as production and quality data. Along with providing data spreadsheets, floor layouts and operation instructions, the operations managers of F4 and F6 also answered many important questions we had concerning the VSMs and flow of operations.

We also obtained information when we visited the factories ourselves. The floor manager in F4, Zhihao Li, answered questions we had concerning the machines used, cycle times, and problems he had encountered in the past. The floor manager in F6, Hua Li, answered questions as well as walked us through the presumed floor layout and the flow of materials. When visiting the plating factory, we were able to see how the machines operate and we were able to acquire time data, as well as inventory data. Visiting the factories in person gave our team valuable data which includes how the factory operates on a regular basis and gave us many ideas for finding areas fit for improvement.

3.1.3 Time Studies

While we received production and work instruction data from the company, as well as observed the factories in motion, we had to conduct our own time studies to get exact information on the cycle times within each factory. In F4, the time studies gave us the observed cycle times for each of the three member's productions lines. We also conducted time studies for the F6 line where we found many areas of improvement, as well as recorded the cycle times.

A time study is a structured process of directly observing and measuring human work in order to establish the time required for completion of that work (http://www.leedsmet.ac.uk/lis/imgtserv/tools/timestudy.htm, 2007). We conducted time studies within the F4 and F6 factories. We recorded the cycle times for individual operations using a stop watch and pre-made tables as seen in Figure 41 in the appendix. These cycle times gave us important information, which we used in our VSMs. The average cycle time told us how well the current operation is doing in relation to the TAKT time. TAKT time is the total available time divided by the number of units in demand for that day. See figure 13 for an example calculation.

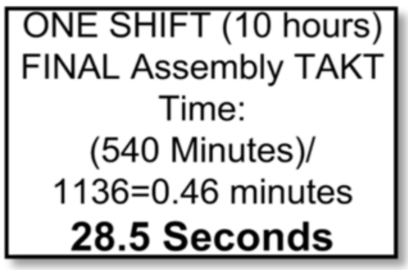


Figure 13 - TAKT Time Calculation

For our data to be comparable, we had to establish a standard way of recording the cycle time. This is not always easy since each process is different; sometimes the cycle times are hard to distinguish. We found the best way was to start and end the observed cycle time, was to start when the operator pushes the 'cycle' button. Another way we recorded cycle times, was to start the stopwatch when the operator inserts a piece into the machine, and then stop the watch when the operator inserts the next piece into the machine. For each operation the number of operators and pieces produced in each cycle was recorded. For data analysis this is important, because the cycle times need to be converted to either two or once pieces at a time. This is necessary since not all machines can do two pieces at a time.

The number of samples for each operation had to be established as well. For the roll forming operation a very small sample size was sufficient, since the process is automated and it outputs pieces at a very repeatable rate. Generally, we took more time samples on operations whose times varied greatly. For example, if the observed cycle times were all 4 seconds long, then we would only record five observations. However, if the observed cycle time ranged from 10 to 30 seconds, then we would record 15 observations. In order to show the cycle times and other obtained information in a meaningful manner, the data is portrayed on VSMs.

3.2 Value Stream Maps

VSMs are used to map work processes, material flow, and information flow. They have a multitude of uses and are generally easy to create and understand. For this project we used Microsoft Visio to create current state and future state VSMs.

Our first objective was to create a current state VSM for the CIS factory. To do this we initially created multiple current state VSMs. These current state VSMs included a high level VSM and various factory's individual VSMs for the specific members and assembly lines. For the future state VSM, we created multiple scenarios, which were used to make a final decision.

For our maps we used the "value stream map" template within the Visio 2007 program. We then listed all the processes included for the corresponding production line. As shown and described in the figure below, we used the different symbols to create our VSMs.

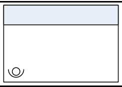
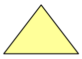
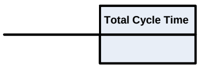
Symbols Used in Microsoft Visio	Meaning of the Symbol
	Process
	Timeline: waiting time and cycle time
	Inventory
	Production Flow
	Total Time

Figure 14 - Value Stream Map Symbols

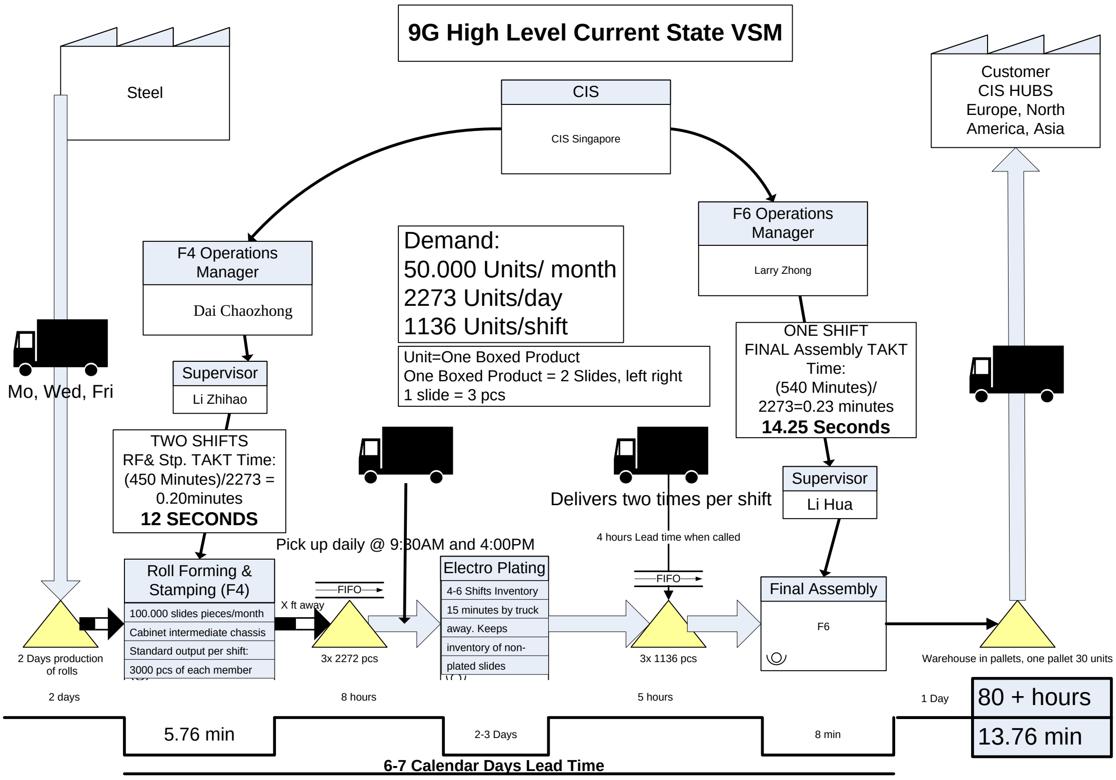
After inserting the appropriate symbols, we inserted the data we collected, as well as the correct names for each operation. After we finished inserting the correct cycle times, we calculated the total cycle time for the specific VSM by adding up the individual cycle times together.

4. Results and Recommendations

In this section we discuss the current state value stream, information flow, and material flow maps. Our team created several types of current state maps, as we mentioned in the previous section. First we created a “high level” VSM, providing an overview of the material flow and transportation between the factories. We also drew a detailed material flow map of F6. After conducting our time studies and collecting relevant information from CIS, we created detailed VSMs for each process. Then we went on to create several different future state maps.

4.1 Current State Maps

The “high level” current state VSM is displayed in the figure below. As seen in this image, the lead time between F4 (the roll forming & stamping) and the finished product, is 6-7 days including the weekend. On the right side of the map, the total machine cycle time, value added time, and waiting time (non-value added time) is



shown. The waiting time is far greater than the value added time, thus increasing the lead time and operating costs due to higher levels of inventory. The cycle time shown for F4 is the longest cycle time for all three processes. Based on the available work time and customer demand, we also calculated the TAKT time for each factory, as shown in the flow chart. There are big operational differences between F4, the plater, and F6. Both F6 and the plater have 10 hour shifts, with a total work time of 9 hours. F4 on the other hand has two 8 hour shifts, with 7.5 hours working time in each. Between shifts in F4, there is tooling maintenance and tooling changes. The differences in operating time and speeds create difficulty to create a smooth process flow. The plater has a high capacity and its cycle times are much shorter than at F4 and F6.

4.1.1 Cabinet Member Production Line

Shown in the figure below is the current state VSM for the cabinet member production line in F4. For this process the cycle time for two pieces are shown. The fastest time is 8.6 seconds and the slowest is 12.8 seconds. The steps in this process are fairly stable. We do not recommend combining or adding steps. However there are 5S improvements for this process, which we will mention in the following section.

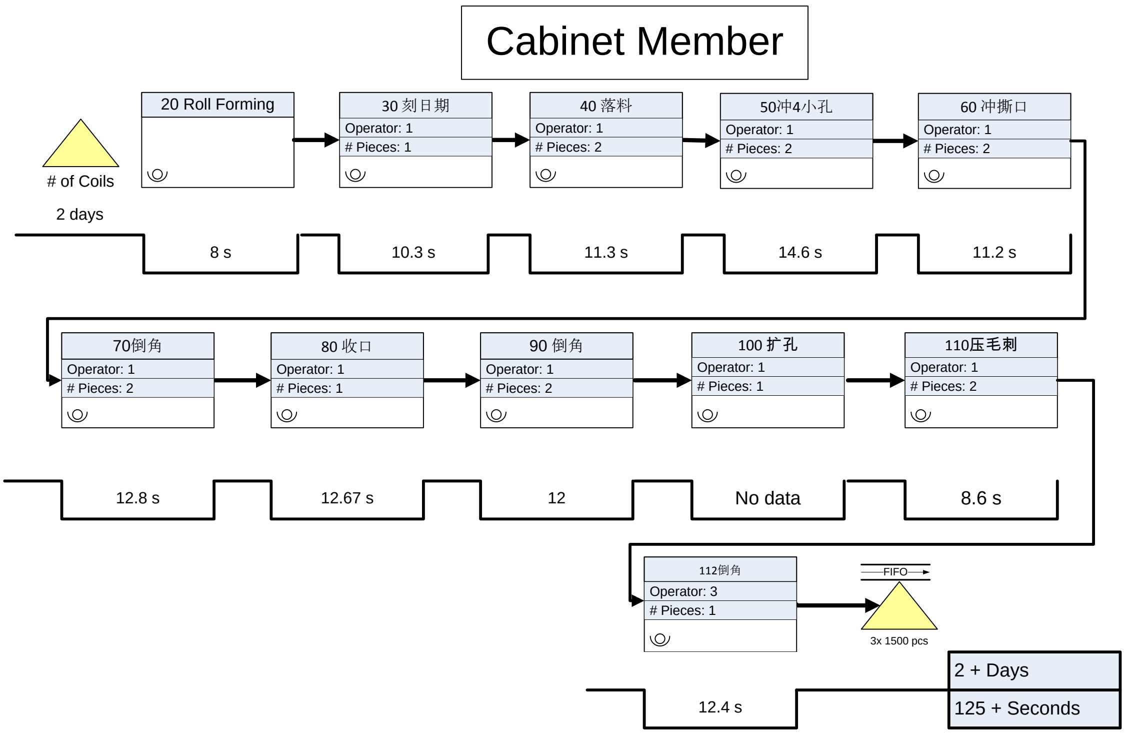


Figure 15 - Cabinet Member VSM

4.1.2 Intermediate Member Production Line

After conducting a time study on the intermediate member in the F4 factory we manually recorded the data onto printed out excel spreadsheets and then later transferred that data into the Excel program. With this data, we calculated the average cycle times as well as the lowest repeatable times. We then input these into the current state and future state VSMs, respectively.

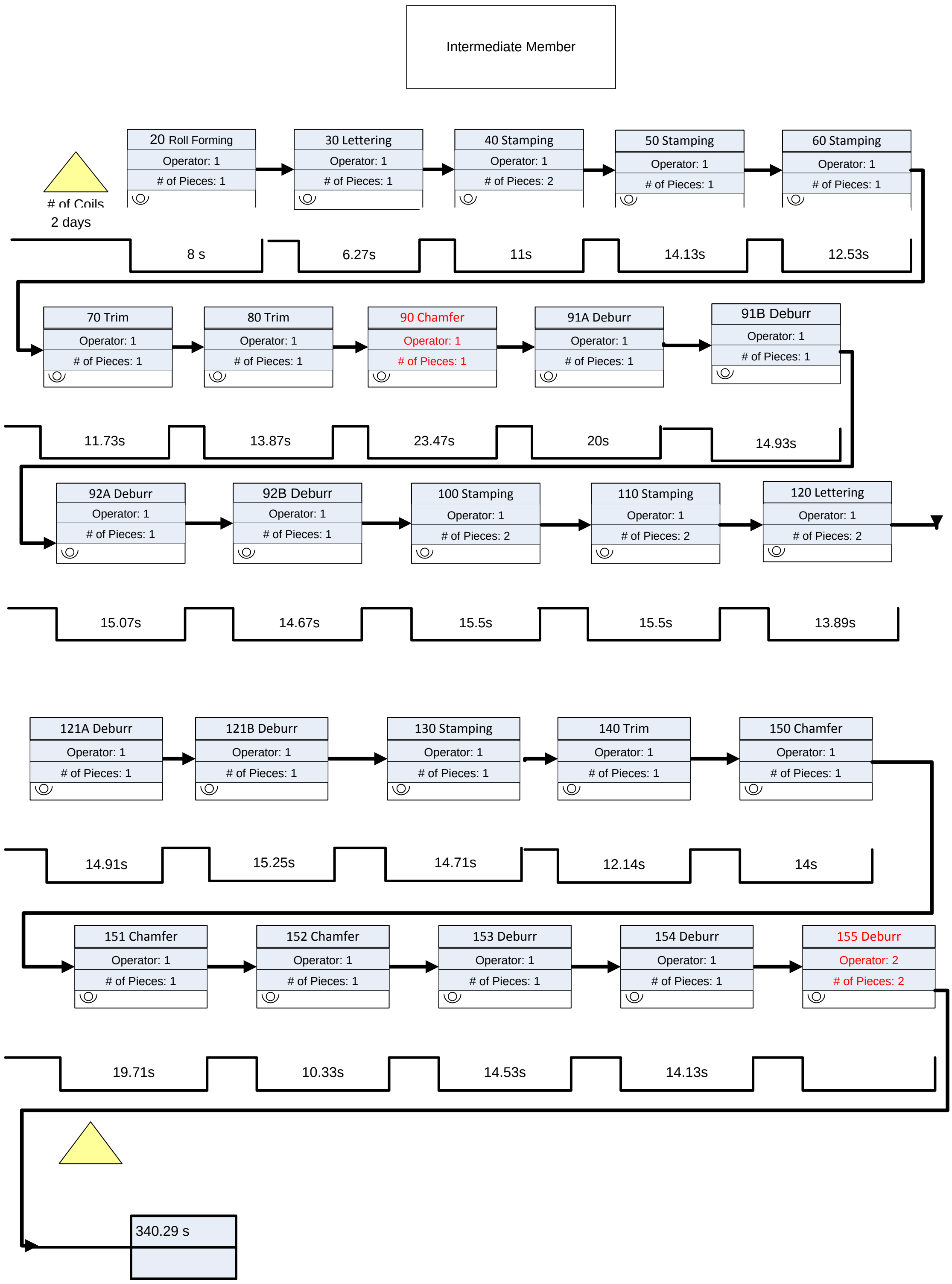


Figure 16 - Intermediate Member VSM

As you can see in the figure above, figure 16, the current state VSM for the intermediate member contains 25 steps. The total cycle time is 340.29 seconds, which is 5.67 minutes. This line is the longest line in this factory and it contains the most steps. We found a “bottle neck” in the middle of the line at step 90. A bottle neck in an operation is a step that takes significantly longer than the rest of the operations, thus slowing down the whole production line. The bottleneck at this step slows down the line and causes a buildup of materials. In the recommendations section of this report, we mention some areas of improvement.

4.1.3 Chassis Member Production Line

The final line in F4 is the chassis member line. This line contains fifteen steps. It starts with roll forming, and undergoes multiple lettering, stamping, and chamfer steps, and finally ends with deburring.

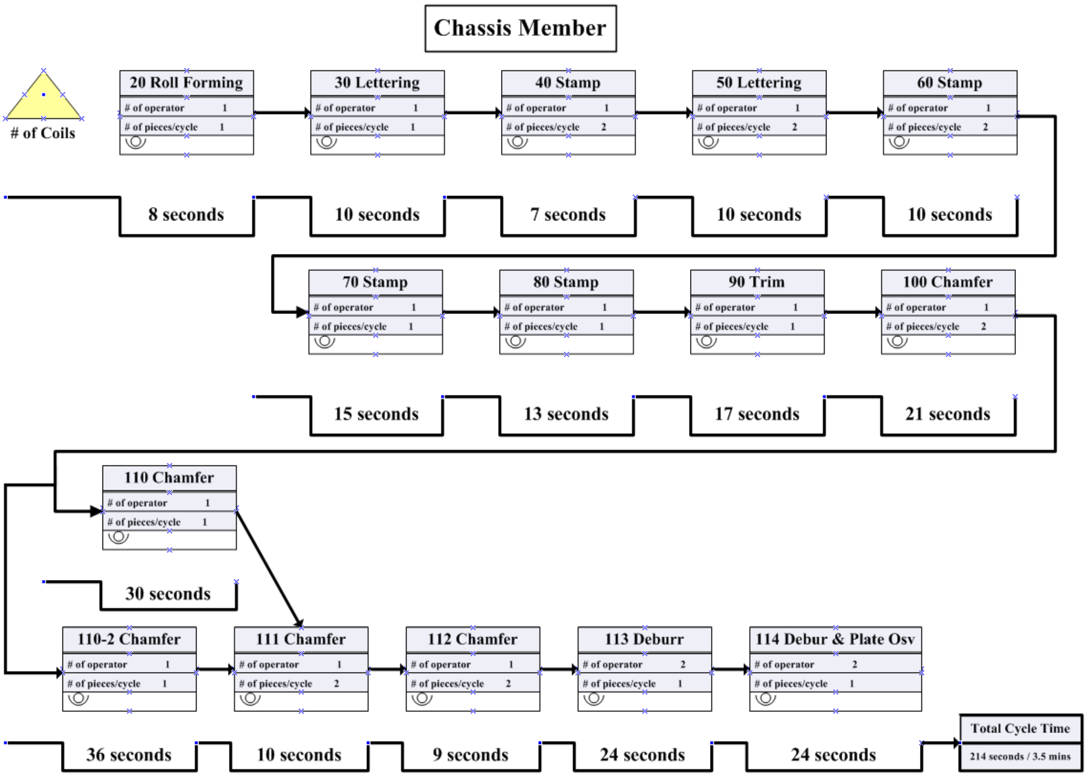


Figure 17 - Chassis Member VSM

The figure above is a current state VSM for the chassis member. The data shown in the timeline includes the average cycle times for each operation. Based on time studies, we found the total cycle time to be 214 seconds, which is about 3.5 minutes. As seen in the figure above, the operation time fluctuates greatly, in which it varies from 7 seconds to 36 seconds. We found two “bottlenecks:” steps 110 and 110-2. Step 110 is chamfer for the left slide, which takes up to 30 seconds. And step 110-2 is chamfer for the right slide with average cycle time of 36 seconds. These two steps take the longest time in the whole production line and slow down the operations. Suggested improvements are shown in the recommendations section of this report.

4.2 Final Assembly in F6

The assembly of the 9G product occurred in F6. The final assembly of the kits took place after the slides, cable mounting arms (CMAs), and instruction packets were assembled individually. The final kit includes two slides (one left and one right), the mounting arm, and instruction booklets. As you can see in the current state VSM for this line below, there are only seven steps, with a recorded total cycle time of 239.77 seconds, which is approximately four minutes.

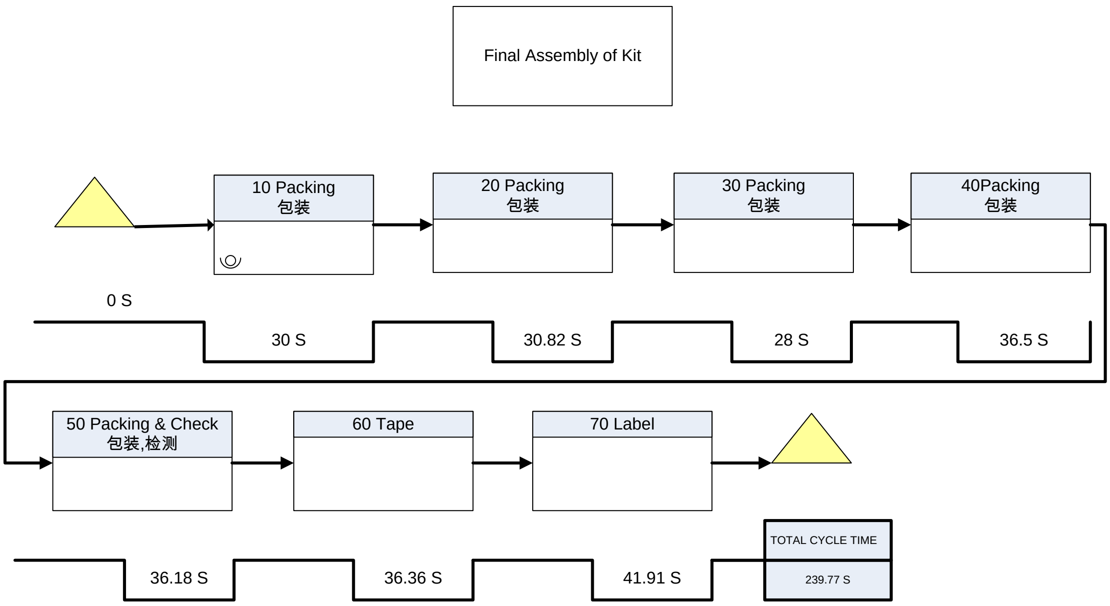


Figure 18 - Cycle Times for Kitting Line in F6

This assembly line differs from the other production and assembly lines because there is no waiting time between the different steps. As you can see from figure 19 below, there is a "one piece flow" motion of materials with zero inventory between operators. In "one piece flow" one unit is produced at a time, as opposed to producing units in larger batches. Once one operation stops, the remaining operators will have to stop working as well, which can create a problem.

Figure 19 - F6 Kitting Line

According to our calculations in Excel, we found the final step, which was the placement of the label on the shipping box, to be the longest operation. However, according to our observations, we found that the bottle neck of the line was the scanning of the entire final kit. In our recommendations section, we provide some ways in which we found will improve this assembly process.

4.3 Current State Information Flow

In order to improve the company's overall lead time we found it was necessary to map out the current information flow. We created several different maps. One for the information flow in F6 and one for the overall information flow between CIS Singapore and CIS Wuxi factories.

4.4 F4 and F6 Communication Flow

Presently there is no standard way of communicating between the CIS factories and the plater. F6 sets a weekly production quota and notifies the plater via phone. Other communication occurs only when quantities change, or problems arise.

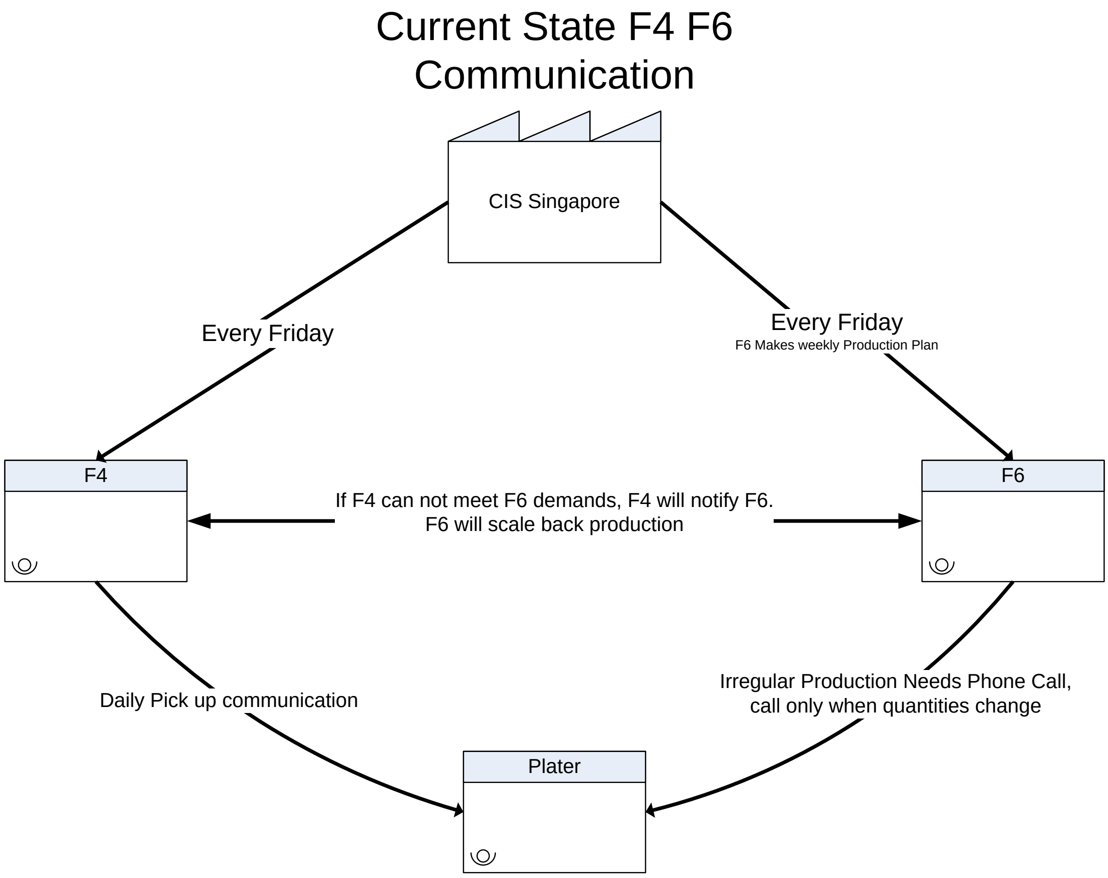


Figure 20 - Current State F4 and F6 Information Flow

4.4.1 F6 information flow

The internal communication flow of F6 is shown in figure 21. As seen in the map, there is a large portion of manual information that is exchanged. When the operator runs out of parts there are two ways for replenishing them. The material handlers are supposed to check the part levels every 15 minutes. As an alternative, if an operator runs out of parts, he will contact the line leader who then will fill out a material request form for the material handler.

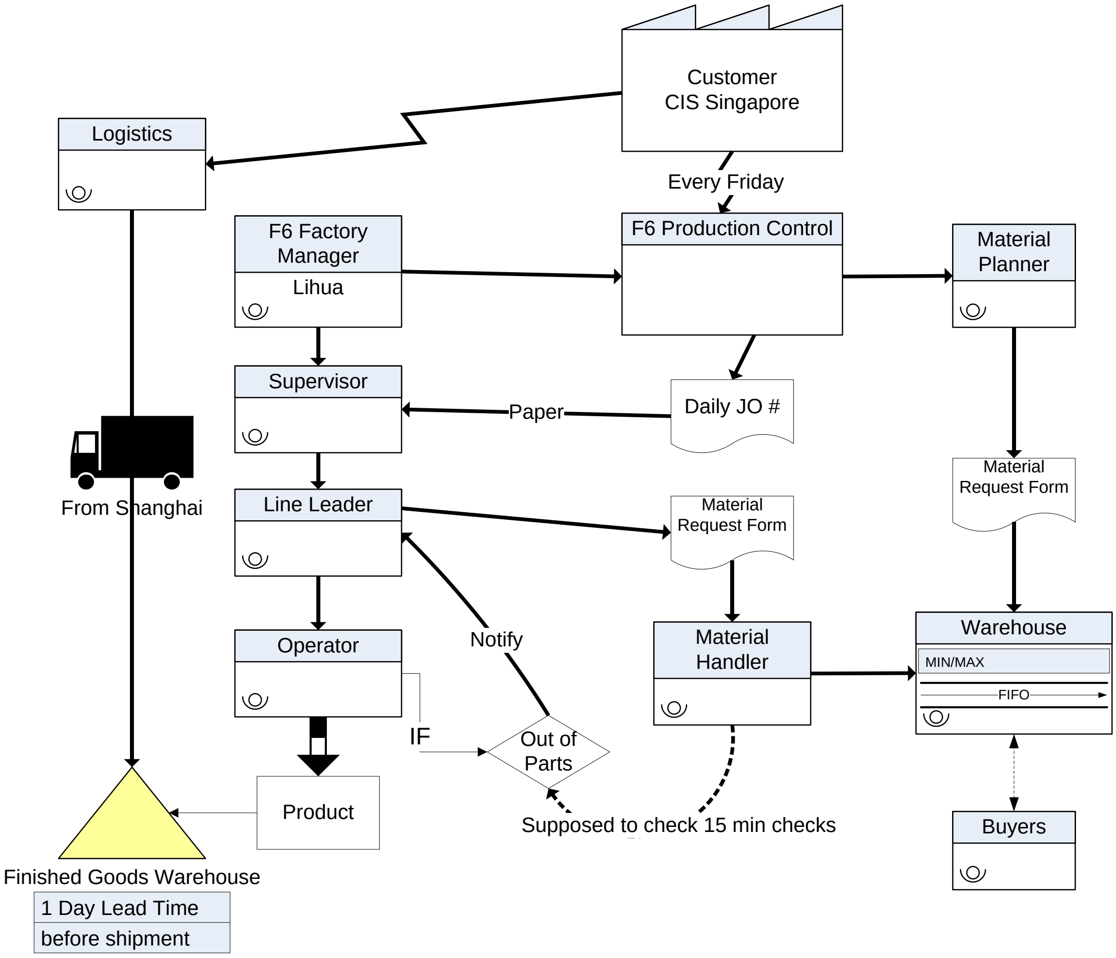


Figure 21 - F6 Information Flow

4.5 F6 Material Flow

The figure below depicts the material flow of factory 6. The red arrow shows the travel of the plated slide members. The slide members arrive at the loading dock (1) and are inspected. After they pass inspection the carts are moved to the storage area (2). From there the slides are moved to the appropriate assembly line. The black arrows show the path traveled.

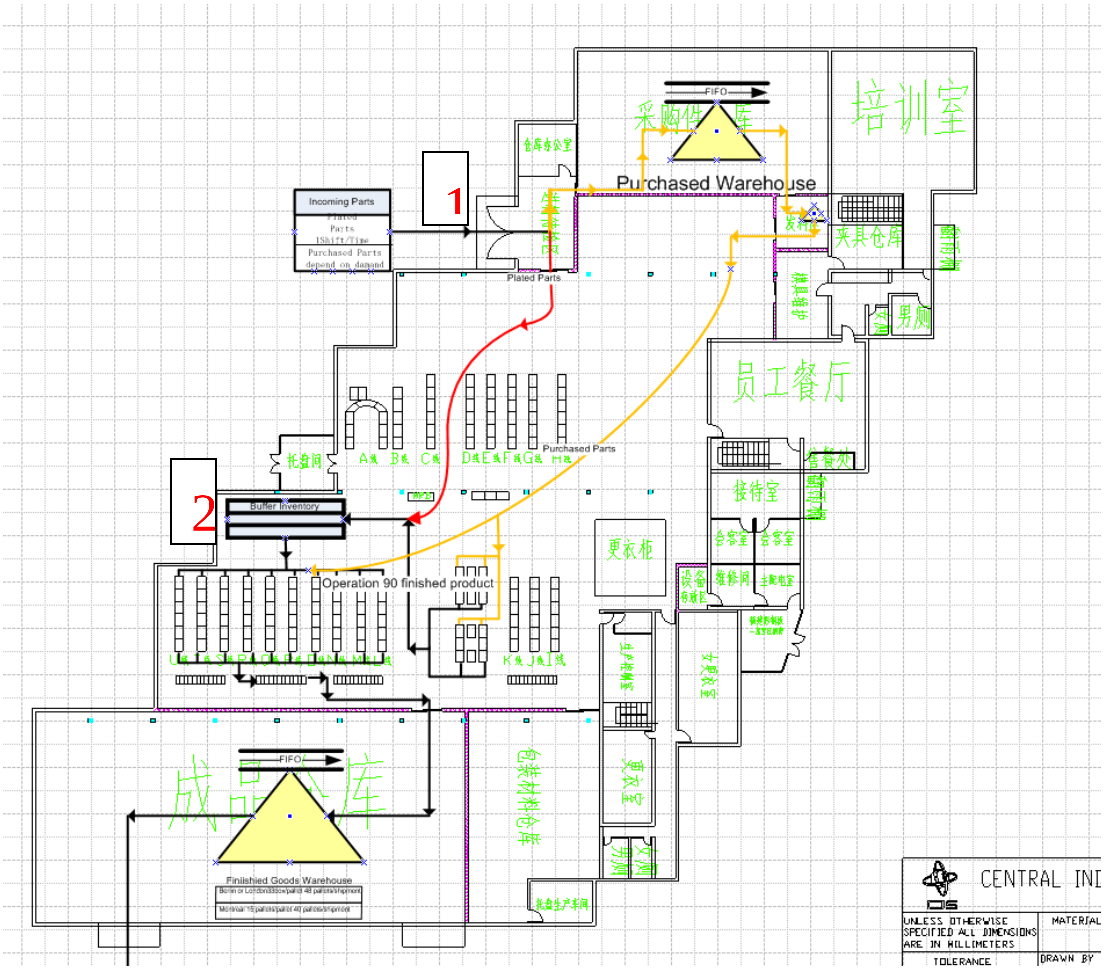


Figure 22 - F6 Material Flow

The yellow arrows show the material flow of the purchased parts. Just as with the slides, the purchased parts arrive at the loading dock (1) and are moved to the purchased parts warehouse after they pass inspection. The purchased parts warehouse operates under the FIFO principle, seen in figure 23.

Figure 23 - Factory 6 Purchased Parts FIFO

As seen in figure 23, CIS uses color coded stickers that represent the month when the parts were received. All the parts received in May receive a sticker with a "5" on it. This gives CIS an easy visual control of its stockroom.

4.6 Recommendations

In this section we will discuss the team's recommendations for CIS. They are twofold. First we will discuss ways of improving the lead time between F4 and the finished product in F6. This is mostly accomplished by reducing the waiting time and inventory sizes. Then we will give some operational improvements for each process in F4, as well as improvement possibilities in F6. We will also outline some information flow and 5S improvements.

4.6.1 Intermediate Member Recommendations

With the objective of the project being to reduce the lead time by at least 50%, we focused mainly on reducing the larger problem areas, such as delivery times and communication with the plater. However, we also found that we can reduce the lead time if we also consider the smaller problem areas as well. The intermediate member production line in F4, as you can see from the current state VSM in section 4.1, contained one major bottleneck in step 90. This step, after talking to the floor manager, utilizes a machine whose tool needs to be changed about every 100 pieces. This factor causes a build up of materials in front of the machine, because it can not keep up with the processes before. We recorded the cycle time for this step to be on average 23.47 seconds, while the other operations within this production line usually had cycle times in the high or mid teens, i.e. 15 or 14 seconds each. The fact that this operation has a longer cycle time than the others means that it is going to slow down the whole process. Our recommendation for the intermediate line is to add another machine and operator to step 90, so that there will not be a bottle neck, and ultimately the line itself will be faster, which will help in reducing the overall lead time.

4.6.2 Chassis Member Recommendations

The cycle time for each operation in Chassis member line fluctuates, as shown in the figure below.

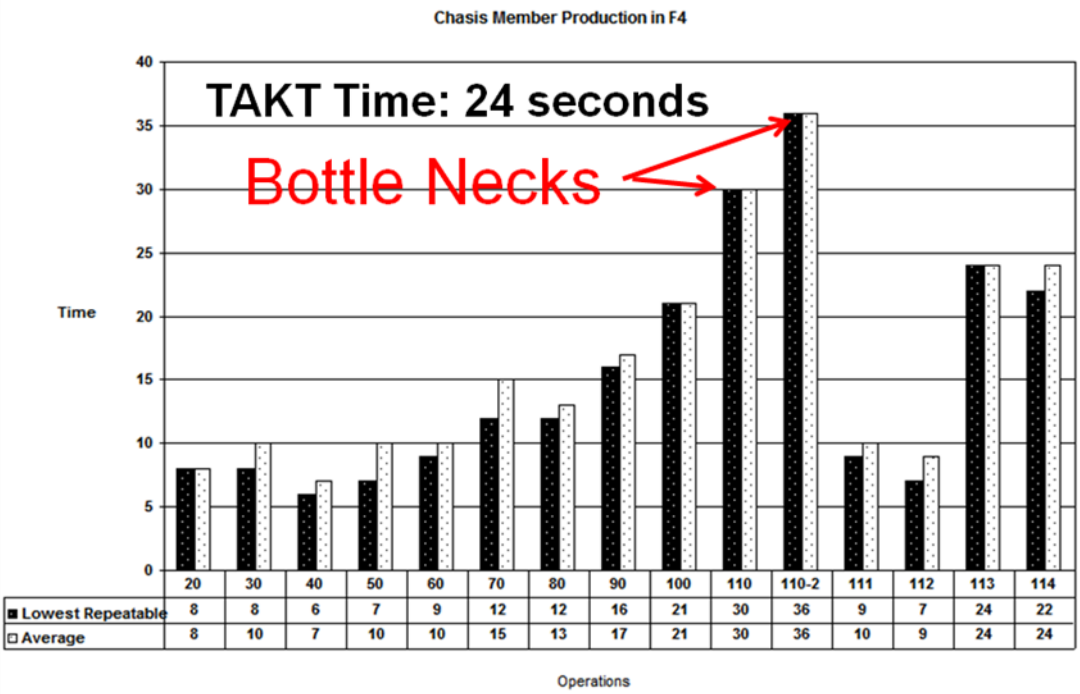


Figure 24 - Chassis Member Production Line in F4

Based on the demand of 50,000 units per month, we calculated the TAKT time in F4 to be 24 seconds. As we can see from the figure, some of the times are above TAKT time. In order to improve production, we tried to even out the cycle times for each operation. We recommended adding an extra machine and operator to each of steps 110 and 110-2. By doing that, we would be able to double the operation speed of these two steps and so reduce the WIP pileup. To a certain extent, this leads to the reduction of total cycle time, since it lessens the total production time for the same amount of demand. We made the same recommendations to steps 60 and 70, as well as steps 80 and 90. Refer to the figure below for more details.

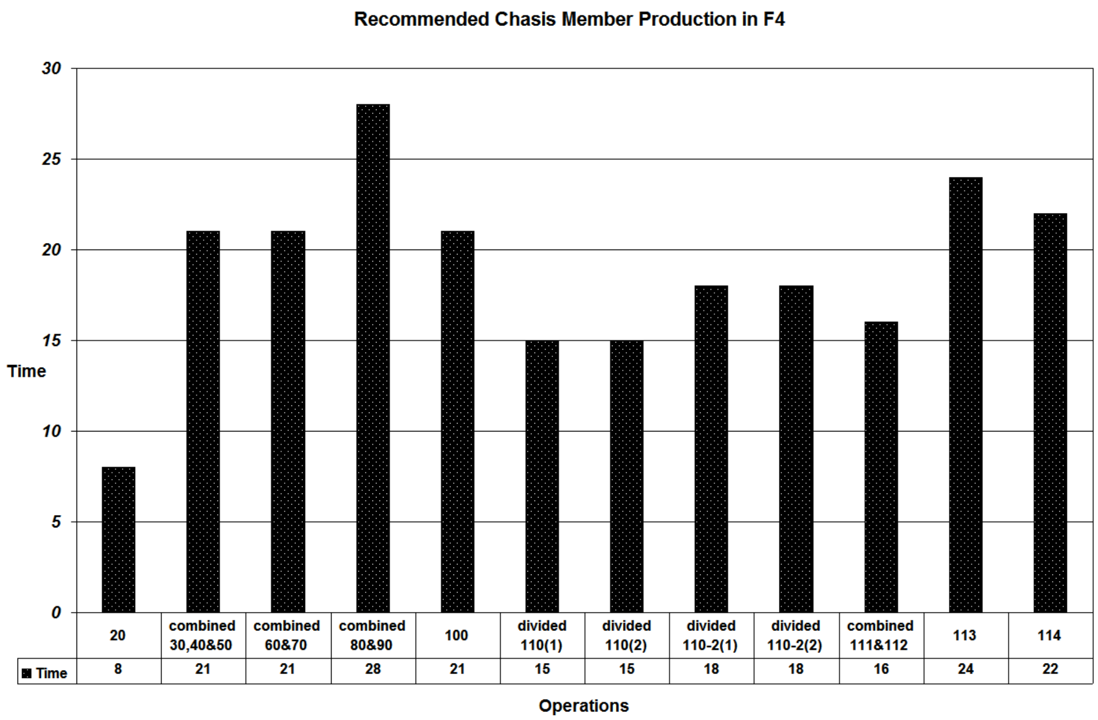


Figure 25 - Recommended Chassis Member Production Line is F4

As seen in the figure, the differences between cycle times are lessened.

4.6.3 Final Assembly in F6 Recommendations

As mentioned in the results section, the line that assembles the final kit in F6 is much different from the other lines in the CIS factories. The reason for this is that this line is a "one piece flow" line, meaning there is no WIP between each step. Once one operation stops or slows down, the remaining operations will stop or slow down also. From our observations, we found that the scanning operation was the longest and most frequent to slow down the line. We came up with a few recommendations to solve this issue.

The operator scans every item inside the box; however they scan each label twice because there are two barcodes for each piece. One scan is for the serial number and the other is for revision number. As seen in figure 26, the serial number is on the left with the revision number on the right. For this particular product there are 8 items to be scanned, yet the operator has to scan in 16 different bar codes. Scanning two bar codes takes twice as much time as it would to scan just one, especially since the revision number label is much smaller than the serial bar code. As of now all the revision numbers are the same, "A00". However, as we found, the revision number was a customer requirement due to past discrepancies. A better and sufficient improvement would be to check each box, or a one lot for the correct revision number.

The easiest solution would be to just modify the test executive software and eliminate the individual revision number scan. The software could be modified to only check for the revision number once a shift, or very 1000 pieces for example.

Figure 26 - Kit Content Verification Software

Another issue with the scanning operation was that the person scanning has to scan items that are in a plastic bag. This sometimes delays the process because plastic bags are often wrinkled and hard to read through for the scanning device. One recommendation we can make for this would be to buy a new scanning device that is more efficient. Another solution would be to place the bar code stickers on the outside of the bags and make sure they can be easily read before they reach the scanning area. Furthermore, the scanner could be modified so that the operator does not have to press the trigger for each scan. The scanner could be in a continuous scan mode, so that the operator just has to move over the bar code. The software could also be modified to accept the bar codes out of order, leaving it up to the operator which bar code to scan first.

Also, on this assembly line, we felt that one of the operations was unnecessary. One of the operators' jobs was to place the instruction manuals and a silica gel packet into the box. We thought that this step could be combined with another, such as the step prior to this, since this operator seemed to stand around with not much to do during the line after he or she placed the items in the box.

A final recommendation for this line would be to have one of the workers designated as the person who replenishes the stock of materials when they run out. We noticed that when operators ran out of materials they had to go to the specific stations to fetch them themselves.

5.5 Information Flow

There are some information flow improvements that will benefit operations and help to reduce lead times. As stated in findings, the current information flow between the factories is only on a weekly basis for planning purposes. All other communication only occurs when there are problems or changes in customer demand. We think that daily operations at the plater and CIS factories would greatly improve if there was a regular and standard exchange of information. This information would range from long term planning to daily production status updates. If there is a tooling issue in F4, the plater should be notified immediately so that the production schedule can be modified accordingly. A MS Visio flow chart of the future state can be seen in figure 38 in the appendix.

5.6 Reducing the lead time by at least 50%

The future state VSM can be seen in figure 24. The highlighted areas show the recommended changes compared to the present state. In F4 and F6 the total cycle times can be reduced, as described in the sections above. The largest part of the lead time is caused by the plating operation. The lead time can be reduced by eliminating the safety inventory of unplated parts. You can see this represented by the dotted box in the picture. In addition, the safety inventory of the plated parts can be reduced to 2-3 shifts. As we have previously discussed, the cycle times for F4 and F6 can be reduced. The delivery times can also be optimized, please refer to figures 39 and 40 in the appendix.

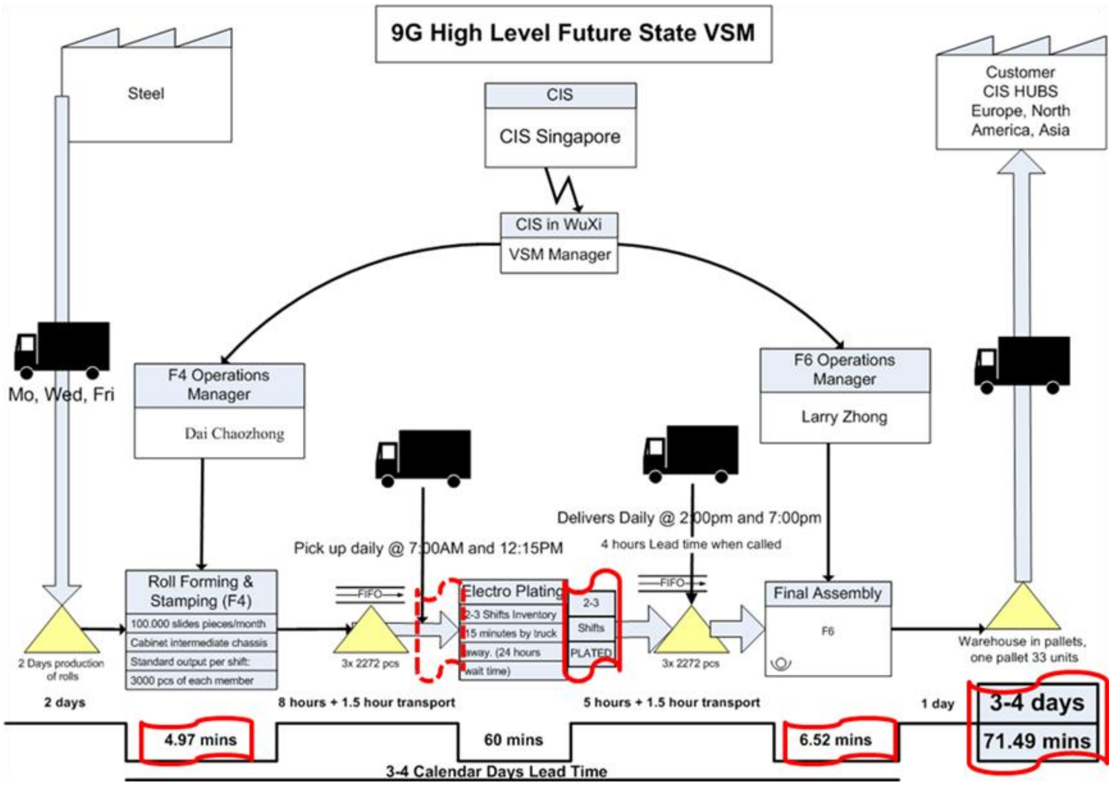


Figure 27 - 9G High Level VSM

5.6 5S Recommendations

In this section we discuss some operational improvements. We will touch on subjects including operator comfort, piece flow and waste of motion.

5.6.1 Factory 4 – Operator Comfort

As observed by the team it seems that for most operators the working height is not comfortable, shown in the figure below.

Figure 28 - Stamping Operators in F4

It seems that the stools they are sitting on are too high, forcing the operator to bend over. Over a long period of time this can create pain and cause the operator to work less efficient, possibly leading to more defects. A simple solution for this would be to change the stool height. This can be done by modifying the current stools, or purchasing new ones that have a more comfortable height. If the operator height is changed, the height of the tables between the machines also needs to change accordingly. Another way to increase operator comfort would be to assign operators to specific machines if they have the right physical characteristics, provided they are qualified to operate both machines. This is especially apparent in factory 6.

Another example for operator comfort can be seen in the chassis line in F4. The deburring step 112 has the cycle button mounted very low, figure 29 and 30, causing the operator to bend downwards and forward.

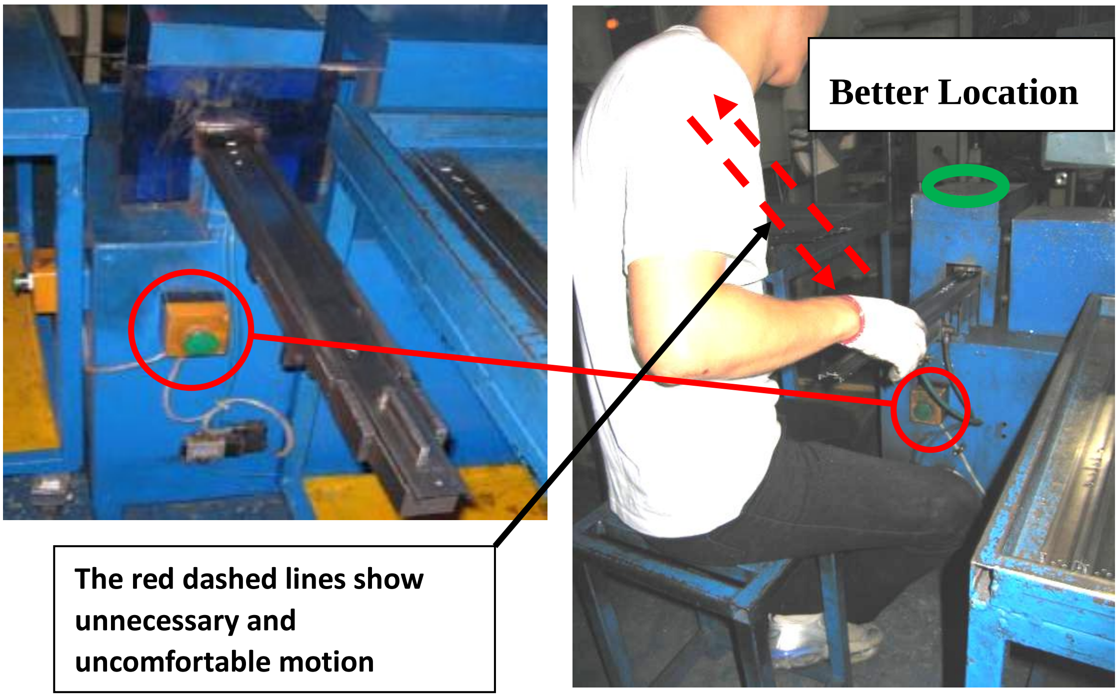


Figure 29 - Uncomfortable Location of Cycle Button **Figure 30 - 5S - Unnecessary Motion**

Figure 30 shows a proposed better location for the cycle button.

5.6.2 Factory 4 – Piece Flow

Throughout the observations at F4, the team also noticed that while there are standard work instructions for each operation, there is no standard procedure of how to handle the slides. In operations as seen in figure 31, two slides are pressed at once.

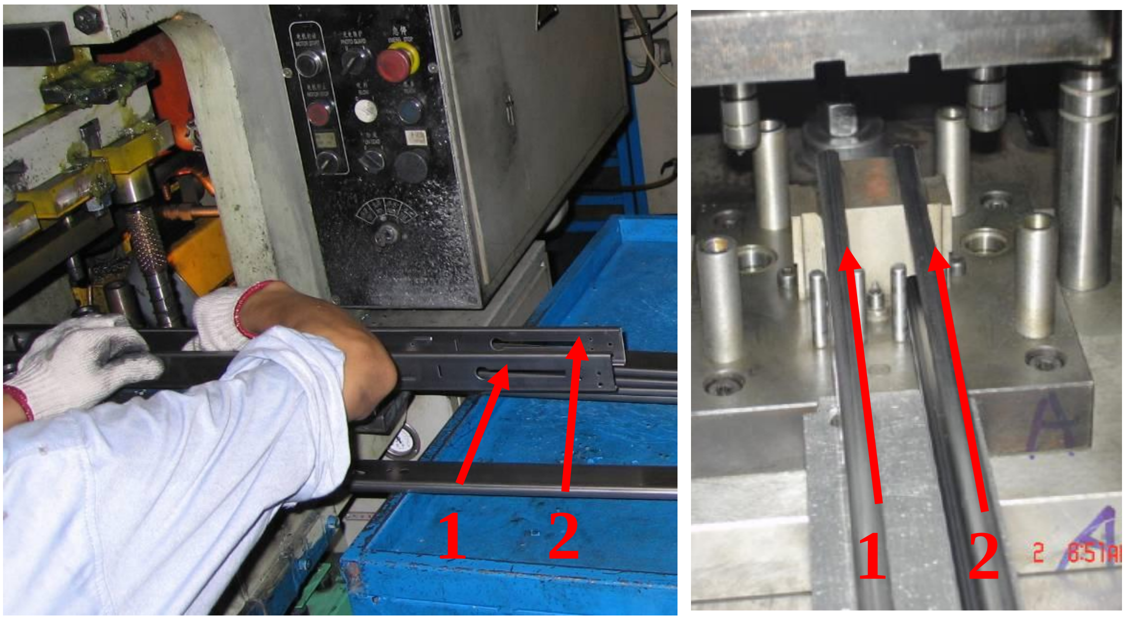


Figure 31 - Slide Placement

Each slide has to be inserted into to the vice from the right side. The team observed that operators sometimes inserted the slide in front first and then the one in the back. To the operator, there may not seem to be a big difference in the order in which the pieces are inserted, but there is. Once the front slide (1) is inserted it covers the back slide (2), so there is no visual way for the operator to find the slot. The difference may seem small, but over the course of the day this does increase the cycle time of that operation. This is just an example; there are many other operations like the one described above that would benefit from a standard piece flow.

5.6.3 Waste of motion

Consider the stamping operations seen in the picture below.

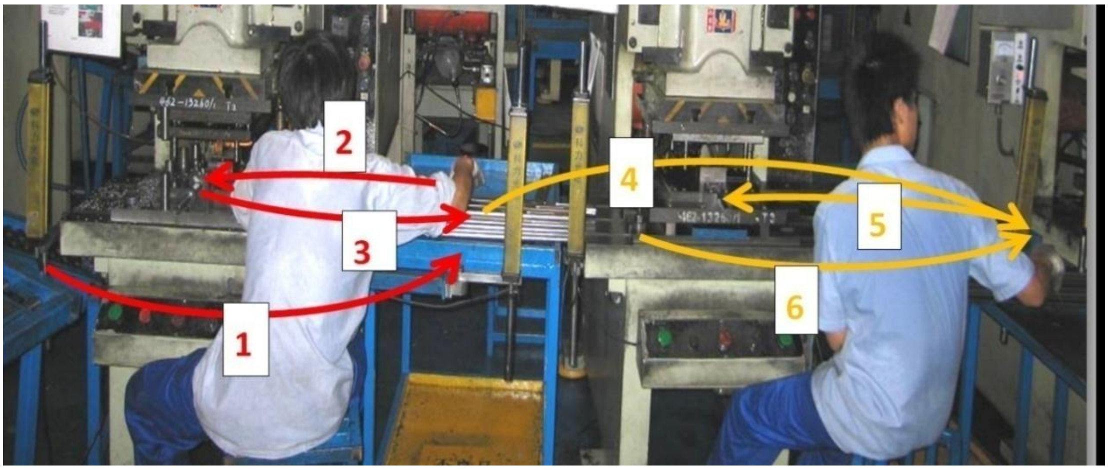


Figure 32 - Current piece flow

The material flows from left to right. For the first operation the operator has to take the material from his left hand side and put it on the table to his right (Step 1). We observed that he took the slides from the left in large batches. The operator would get up from his chair and take 10 or more slides and set them on the table. Then he has to take the material from the table to his right and insert the part in the machine to his left (Step 2). When he is finished the operator will place the part again on the table (Step 3) for the next operator. Operator 2 repeats the same flow as just described. See figure 32.

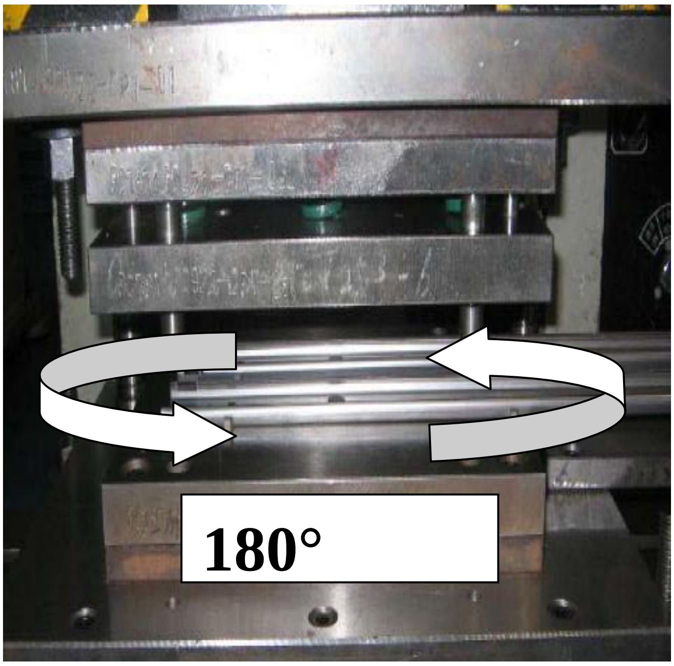


Figure 33 - Modify Tooling

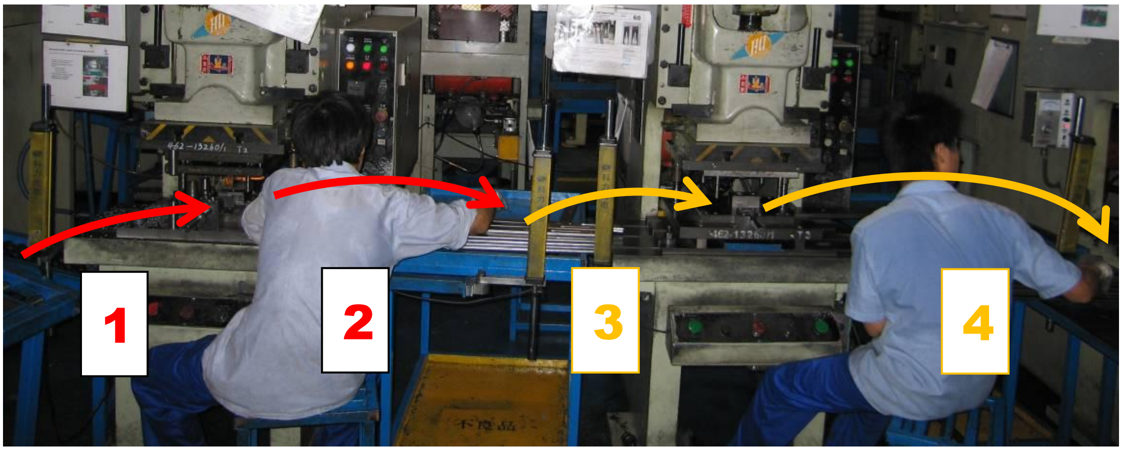


Figure 34 - Better piece flow

Ideally the pieces would flow only to the right, never back to the left. (Figure 34) This is considered a waste of motion. Also the operator handles the parts more often than he has to, another waste.

This problem could be solved by redesigning the vices so that the pieces are inserted from the left, rather than the right. (Figure 33)

6. Conclusions

It is feasible to reduce the current lead time by 50 % between F4 and the final boxed product. The biggest part of the current lead time is inventory time. Inventory levels directly affect the lead time. The more work in progress (WIP) there is, the longer the lead time will be.

The team recommends that by eliminating the safety inventory of un-plated parts, that alone will reduce the lead time by 1-2 days. Currently, the plater has an inventory of 2-3 shifts worth of slides in safety inventory, of both plated and un-plated parts. In total an inventory of 4-6 shifts. Optimizing the pick up and delivery times also contributes to reducing the lead time, though not as much as lowering the inventory.

Value stream mapping has proven to be an effective way to analyze a company’s current production state and point out problem areas. The visual nature of value stream mapping, by combining information and material flow on one map, depicts how the two relate to the lead time. We recommend to CIS to build on the WPI/HUST teams’ efforts and to utilize the methods developed in this project.

7. References

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Appendix A: F6 Information/ Material Flow

Figure 35 shows the present state information and material flow in factory 6. There is verbal, electronic and paper information flow. Some of the steps, such as when an operator runs out of parts, require too many steps until the parts are refilled.

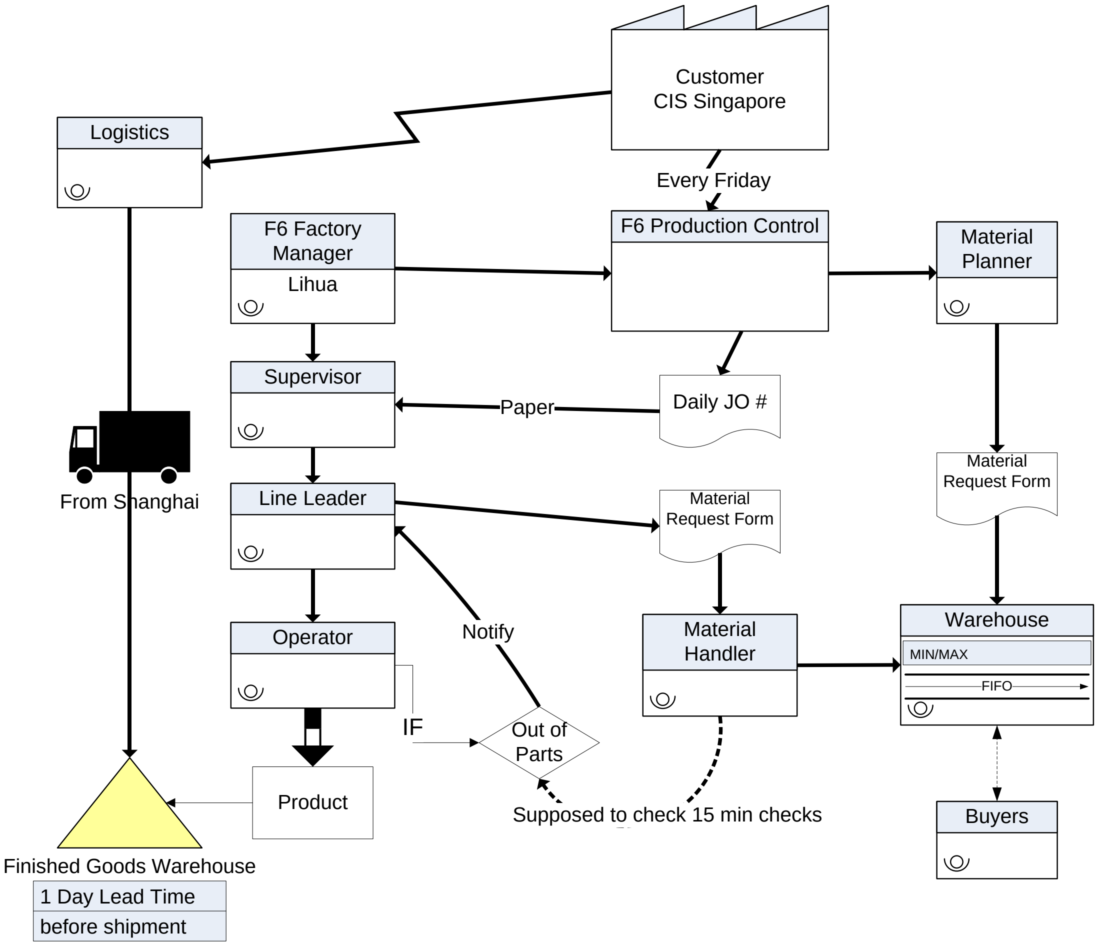

Figure 35 - F6 Information Flow / Material Flow

Appendix B: F4 Information/Material Flow

Like Appendix A this flowchart depicts the information and material flow of F4. It shows how daily operations run. Production control issues a daily job order and material list to the supervisors in F4. The material comes from the supplier, shown on the left, and goes to the plater after being processed in factory 4.

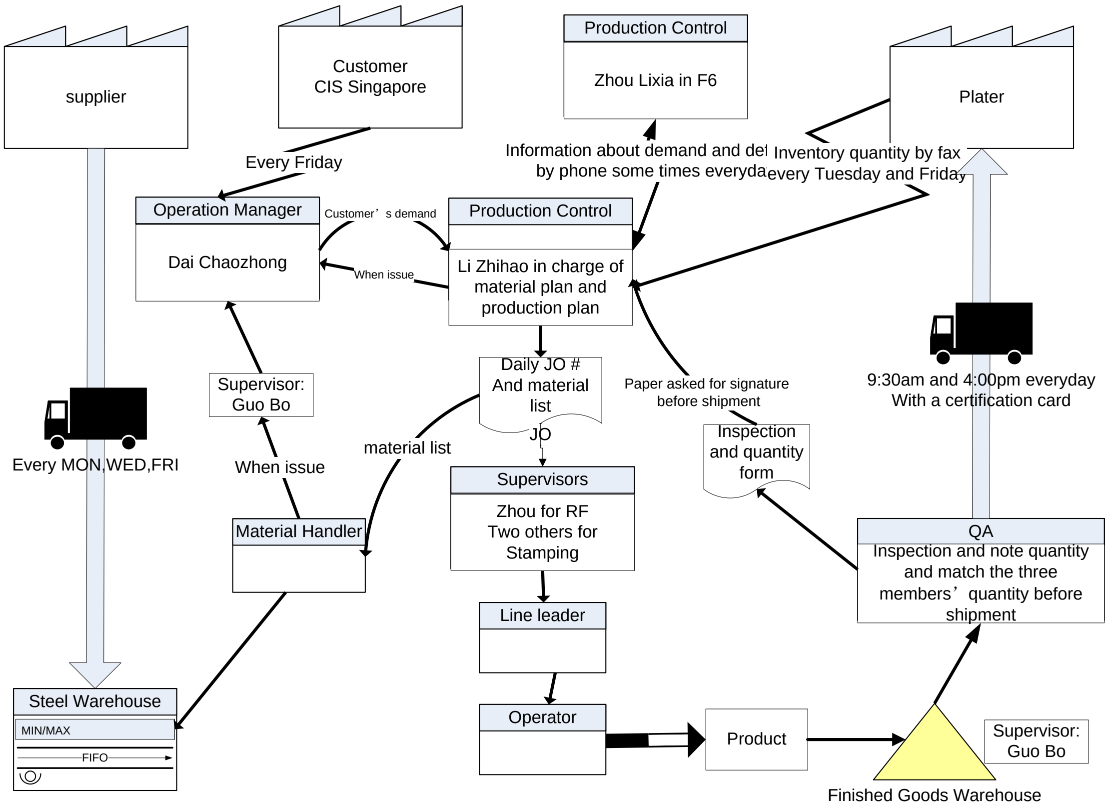

Figure 36 - F4 Material and Information Flow

Appendix C: Future State Information Flow

The flowchart below shows a possible future state of communication flow between CIS Singapore and the Wuxi factories. The team proposes to have weekly production plan conferences among all three factories, to better streamline operations.

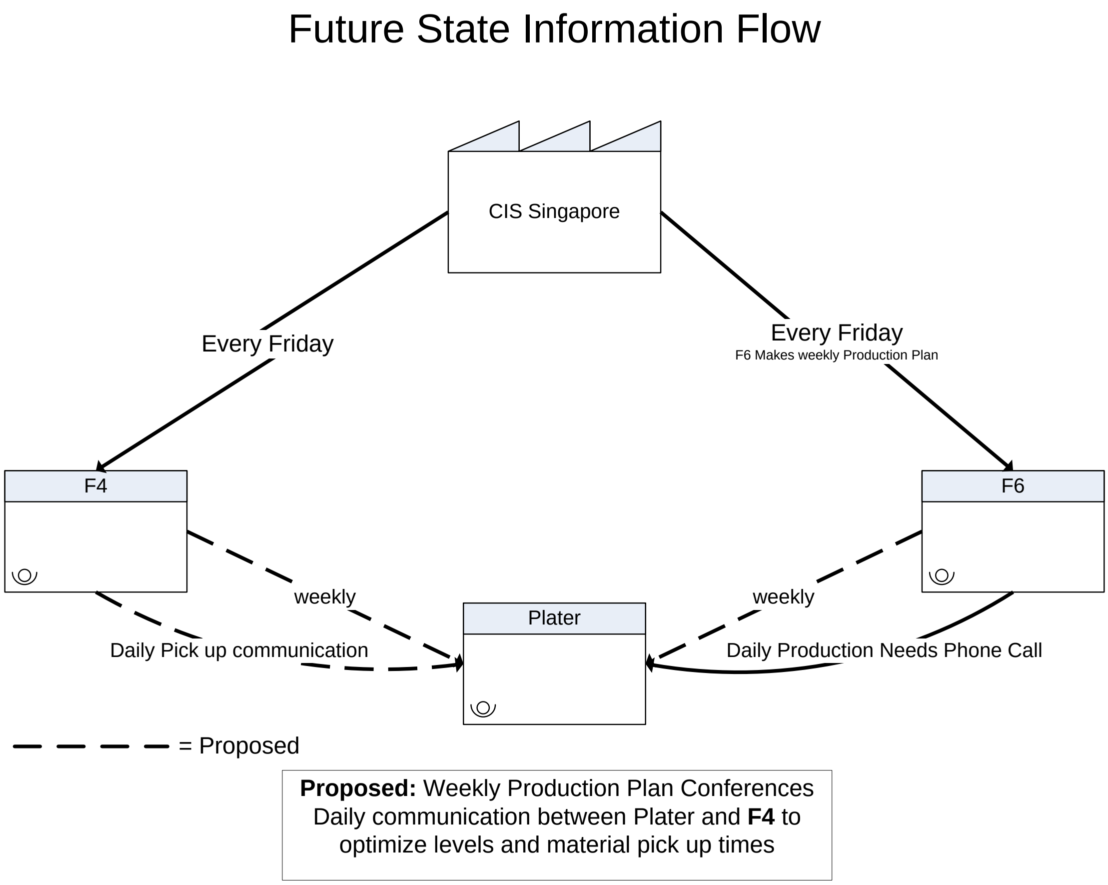

Figure 37 - CIS Future State Information Flow

Appendix D: Improved Delivery/Pickup Times

Shown here is the improved flow of slides. The pickup and delivery times are optimized, as well as the safety inventories at the plating operation. The lead time is calculated by the date codes on the slides.

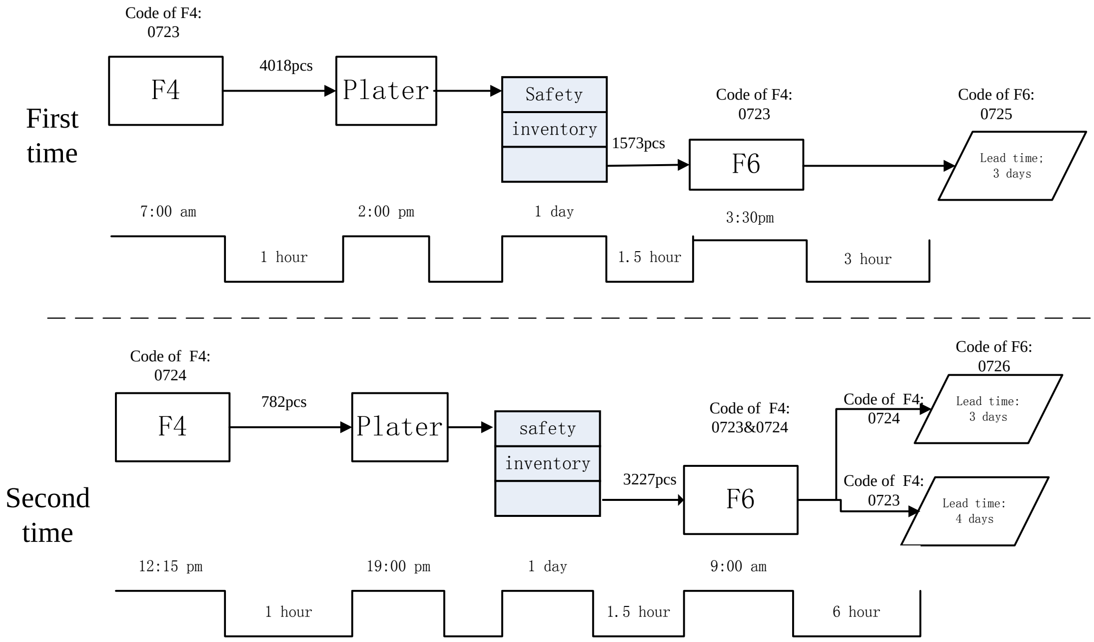

Figure 38 – Improved Delivery and Pickup Times

Appendix E: Current Delivery/Pickup Times

The chart below “follows” one slide from F4 to final product, showing the lead time.

The time spent at each operation, in transit and waiting time are also shown.

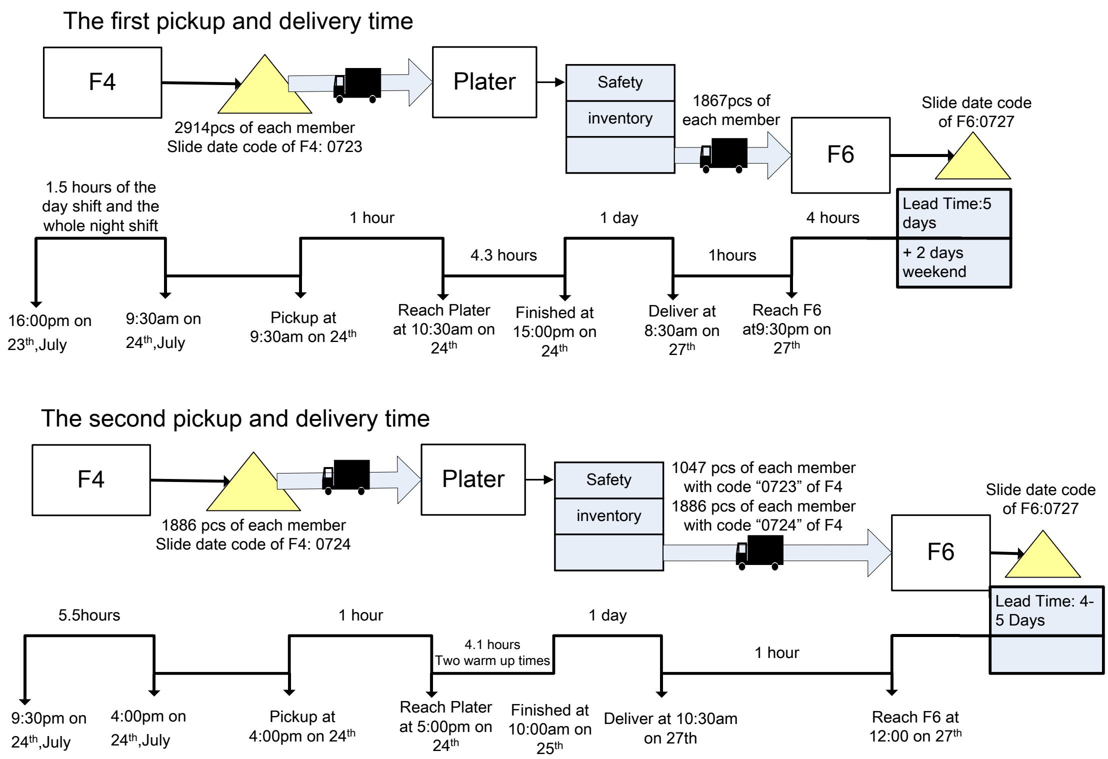

Figure 39 - Current Delivery and Pickup Times

Appendix F: Cycle Time Recording Sheet

This table was used to record cycle times in F4 and F6. For each operation other relevant information, such as the number of operators, numbers of pieces per cycle, batch size and comments were noted.

Cabinet Member **Date:** **Time:**

Operation	Cycle Times (s)	Cycle Times (s)	Cycle Times (s)	Cycle Times (s)	Cycle Times (s)	Cycle Times (s)	Cycle Times (s)	# Operater	# of pieces per cycle	Batch Size	Comments
20											
Waiting											
30 刻日期											
Waiting											
40 落料											
Waiting											
50 冲 4 小孔											
Waiting											
60 冲撕口											
Waiting											
70 度倒角											
Waiting											
80 收口											
Waiting											
90 度倒角											

Figure 40-Cycle Time Recording Sheet