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**An analysis of modelling tools for lean supply chain: A case study application**

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**ABSTRACT**

A lean supply chain is imperative to compete in today's market. In order to achieve a lean supply chain, the first stage adopted by a number of researchers has been to develop and apply diagnostic tools either within internal or extended supply chains. In general, such tools have proved useful in their original settings, but have often failed to provide a wider applicability to analyse in a supply chain level. Therefore the purpose of this paper is to discuss about the application and challenges faced in constructing a lean supply chain. The different modelling tools will be analysed and evaluated in order to select the most appropriate tool for constructing a lean supply chain. The most appropriate tool will be

applied to a case study in order to evaluate how the tool is put into practice. This testing will show a number of shortcomings of the approach.

Keywords: Business process, supply chain redesign, mapping tool

## **1. INTRODUCTION**

Supply chain management is vital for performance, cost minimisation and customer satisfaction. Add the concept of Lean, the elimination of waste that can make a supply chain more efficient and competitive (Plenert, 2007). Manufacturing companies need to redefine and redesign their supply chain systems to tackle the competitiveness demanded by the challenges of current markets (European Commission, 2004). A lean supply chain is imperative for the companies to compete in today's market. Every organisation desires to be part of a lean supply chain which responds very quickly and flexibly to changing customer demands and fulfils orders at a relatively low cost without having to carry a lot of inventories (Srinivasan et al., 2005).

The focus of traditional lean manufacturing is delivering value to the customer. The primary mechanism for improvement is removing waste from the organisations processes with the customer's needs in mind. The lean supply chain concept is built on the broader goal of providing value to the customer by optimising the performance of the supply chain as a system (Phelps et al., 2003). In order to achieve a lean supply chain, the first stage adopted by a number of researchers has been to develop and apply diagnostic tools either within internal (one company) or extended supply chains. It is necessary to have practical tools that will support the redesigning process for lean supply chain systems. In general, such tools have proved useful in their original settings, but have often failed to provide a

wider applicability to analyse in a supply chain level. Moreover, to date, there is no comprehensive work to review and compare existing techniques and tools for constructing a lean supply chain systematically. Current literature has aimed only one tool to apply and highlighted mainly the success of the tools' application but lack of the actual practical difficulties that the practitioners have had to face, either the keys to obtain a maximum effectiveness from the tools (Lasa et al., 2008).

Therefore the purpose of this paper is to discuss about the application and challenges faced in constructing a lean supply chain. The main modelling tools are analysed and evaluated in order to select the most appropriate tool for constructing a lean supply chain. The most appropriate tool is applied to a case study in order to evaluate how the tool is put into practice. The application will show whether the selected tool can be highly effective in diagnosing waste and helping to pinpoint how incremental improvement programs may yield considerable advantage. This testing also shows a number of shortcomings of the approach.

This section presents the background of the research, its aim, the research approach, and followed by its scope. The remainder of the paper is organised as follows. Section 2 reviews the literature on lean supply chain and supply chain modelling tools, and followed by a comparison of supply chain modelling tools. Section 3 presents the application of the approach in a case study. Finally, concluding remarks and future research directions are provided.

## **2. LITERATURE REVIEW**

This section presents the literature review of the research starting with lean supply chain, supply chain modelling and design tools are then described and finally followed by a comparison of supply chain modelling tools.

### **2.1 Lean supply chain**

Firstly, it is important to make some key definitions so as to ensure there is no ambiguity in further discussions. The following definitions related to “lean” are described. The study of lean can be traced back to the Toyota Production System (TPS) with its focus on the reduction and elimination of waste within the factory environment. “Waste” is defined as anything that interferes with the smooth flow of production (Macduffie and Helper, 1997). It is identified into seven types: waste from overproduction, waste for waiting time, transportation waste, inventory waste, processing waste, waste of motion, and waste from product defects (Taj, 2008). The Just in Time (JIT) philosophy was developed in the framework of this new production system and evolved exactly out of the need of the Japanese industry to survive in the post-war global market (Papadopoulou and Ozbayrak, 2005). As the popularity of the system increased and more companies implemented JIT, the focal point of the research in the early 1980s was “Lean Manufacturing”. According to Jamshidi (2009), lean manufacturing is aimed at the elimination of waste in every area of production including product development process and factory management activities. Its goal is to incorporate less inventory, less time to develop products, and more efficiency to become highly responsive to customer demand while producing top quality products in the most efficient and economical manner possible.

The lean manufacturing application was not extended to other parts of the supply chain where large quantities of finished product were stock-piled in anticipation of customer orders (Bruce et al., 2004). Despite the presence of lean manufacturing facilities in the supply chain where throughput times were being dramatically reduced, customers would still experience significant delays for delivery of their orders (Fisher, 1997; Bruce et al., 2004). Further the idea of a lean enterprise concept was introduced by Womach and Jones in their 1994 Harvard Business Review article “From Lean Production to the Lean Enterprise”. They view the lean enterprise as a group of individuals, functions and legally separate but operationally synchronised companies. The goal is to apply lean techniques that create individual breakthroughs in companies and to link these up and down the supply chain to form a continuous value stream to raise the whole chain to a higher level. Nightingale and Milauskas (1999) gave the definition of “lean enterprise” as an integrated entity that efficiently creates value for its multiple stakeholders by employing lean principles and practices. The design of the lean enterprise incorporates lean attributes and values as baseline requirements for the re-creation of the enterprise. It is apparent that lean enterprise concept has a broader perspective than the traditional lean concept. The lean enterprise philosophy is depicted as an overall organisational philosophy that crosses the limits and boundaries of the various departments in the company, and is applicable beyond the factory floor (Papadopoulou and Ozbayrak, 2005). It can be concluded the aim of lean enterprise is at the supply chain level and the concept of lean enterprise is aimed to adopt a lean supply chain.

A major part of the traditional lean concept is waste reduction, but in the supply chain context, optimal operations may mean increasing apparent waste in one part of the supply chain to allow a larger reduction elsewhere (Phelps et al., 2003). The basic goal of lean

supply chain is to optimise supply chain performance as a whole which involves the intelligent application of lean principles across the supply chain (Phelps et al., 2003). Hence, it is necessary to the supply chain companies to work together to improve their scheduling, shipping, and processes, allowing them to hold only the amount of strategically located inventory necessary to guard against flow interruptions. This may seem obvious that it required coordinated efforts across companies in the supply chain which is often difficult to implement. Productivity Press (2006) describes the process being used to create a lean supply chain as follows:

1. Identify and prioritise suppliers to work with and gather information to establish cost and cycle time reduction targets.
2. Engagement and team formation.
3. Baseline assessment and continuous improvement plan by looking at three value streams (product flow, information flow and technical problem solving).
4. Continuous improvement events.

While Phelps et al. (2003) presents five steps to achieve lean supply chain which briefly explain to (1) select the target supply chain, (2) assess the current state of the supply chain, (3) determine how best to move forward, (4) implement change and (5) share results with current and potential customers as well as other suppliers in the same and other supply chains.

From the literature review in this section, it is found that there are many research papers documented about the implementation of specific lean practices especially on the factory floor (Papadopoulou and Ozbayrak, 2005) such as lean production experience ( e.g. Sohal and Egglestone, 1994), lean manufacturing implementation (e.g. Worley and Doolen, 2006; Mortimer, 2006; Anand and Kodali, 2008; Pham et al., 2008; Jamshidi, 2009),

benchmarking for assessing lean manufacturing implementation (e.g. Gurumurthy and Kodali, 2009), lean manufacturing performance in China (e.g. Comm and Mathaisel, 2005; Taj, 2008). On the contrary, little research work had been developed regarding the greater issue of lean implementation as a holistic process especially at the enterprise and supply chain level (Papadopoulou and Ozbayrak, 2005). The limited research work on lean supply chain includes lean enterprise implementation (e.g. Phelps et al., 2003; Papadopoulou and Ozbayrak, 2005; Cagliano et al., 2006) and lean supply (e.g. Bruce et al., 2004). In order to select the right tool to construct a lean supply chain, the characteristics of lean supply chain from the literature review in this section can be concluded as follows:

- Lean supply chain refers to the total enterprise and the supply chain.
- Lean supply chain requires rooting out everything that is non-value-added or waste.
- Lean supply chain is a dynamic process of change driven by a systematic set of principles and best practices aimed at continuous improvement as a whole.
- Lean supply chain requires coordinated efforts across parties in the supply chain.

## **2.2 Supply chain modelling and design tools**

Many researchers and practitioners agree the necessity of using supply chain modelling and design tools to manage the supply chain effectively (Li et al., 2002). A number of supply chain modelling and design tools have been proposed to describe the supply chain from different aspects. As a result of the literature review the following were found as the most frequently used and therefore they are considered as the main techniques. The most important characteristics of each tools are discusses below.

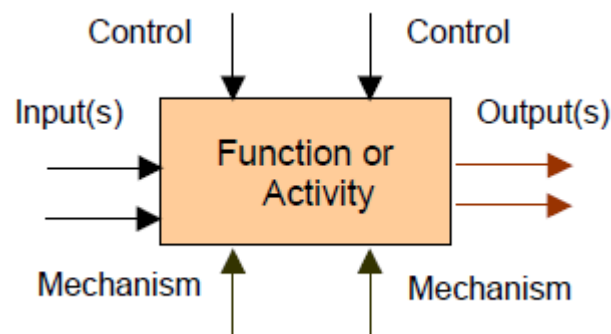
### **2.2.1 IDEF**

The Integrated Definition for Function Modelling (IDEF) is a family of methods that supports a paradigm capable of addressing the modelling needs of an enterprise and its

business areas (Saven, 2003). IDEF's roots began when the US Air force sought to increase manufacturing productivity through systematic application of computer technology in the Integrated Computer-Aided manufacturing (ICAM) program. The IDEF family is used according to different applications. Sixteen methods, from IDEF0 to IDEF14 (and including IDEF1X), are each designed to capture a particular type of information through modelling processes. IDEF methods are used to create graphical representations of various systems, analyse the model, create a model of a desired version of the system, and to aid in the transition from one to the other. For business process modelling, the IDEF0 standard is the most popular process modelling on the market. The very strict rules in IDEF0 make it suitable for implementation as computer software (Saven, 2003).

The IDEF0 Functional Modelling method is designed to model the decisions, actions, and activities of an organisation or system (IDEF, 1993). It is used to specify function models, which are "what do I do?" models. These show the high-level activities of a process indicating major activities and the input, control, output and mechanisms associated with each major activity. The processes can be further decomposed to show lower-level activities until the model is as descriptive as necessary for the decision-making task at hand. IDEF0 is capable of graphically representing a wide variety of business, manufacturing and other types of enterprise operations to any level of detail. It provides rigorous and precise description, and promotes consistency of usage and interpretation. It is well-tested and proven through many years of use by government and private industry. Nevertheless, one weakness of IDEF0 addressed by IDEF(1993) is the tendency of IDEF0 models to be interpreted as representing a sequence of activities. While IDEF0 is not intended to be used for modelling activity sequences, it is easy to do so. The activity may

be placed in a left to right sequences within a decomposition and connected with the flows. It is natural to order the activities left to right because, if one activity outputs a concept that is used as input by another activity, drawing the activity boxes and concept connections is clearer. Thus, without intent, activity sequencing can be imbedded in the IDEF0 model. Furthermore, IDEF0 is a qualitative tool that overlooks the quantitative data of the production system (Wu, 1996). The IDEF0 format is shown in Figure 1.



**Figure 1: A generic IDEF0 diagram (Source: IDEF,2009)**

### 2.2.2 SCOR model

The Supply Chain Operations Reference-model (SCOR) is a process reference model that has been developed and endorsed by the Supply Chain Council as the cross-industry standard diagnostic tool for supply chain management (Supply Chain Council, 2010). SCOR model integrates the well-known concepts of business process re-engineering, best practices, and process measurement into a cross-functional framework (Huan et al., 2004). The model provides a business process framework with standard descriptions and interdependencies among processes. The aim is to meaningfully map supply chains and supply chain activities with varying complexities across multiple industry-verticals (Gulledge and Chavusholu, 2008). At the highest level, the SCOR model is organised into five business process types: source, make, deliver, plan and return. These business processes represent the vertical-neutral abstractions from all demand/supply planning,

purchasing/procurement, manufacturing, order entry and outbound logistics, and returns processing activities.

According to Supply Chain Council (2010), SCOR provides three-levels of process detail. Each level of detail assists a company in defining scope (Level 1), configuration or type of supply chain (Level 2), process element details, including performance attributes (Level 3). Below level 3, companies decompose process elements and start implementing specific supply chain management practices. It is at this stage that companies define practices to achieve a competitive advantage, and adapt to changing business conditions. SCOR is a process reference model designed for effective communication among supply chain partners. As an industry standard it also facilitates inter and intra supply chain collaboration, horizontal process integration, by explaining the relationships between processes (i.e., Plan-Source, Plan-Make, etc.). It also can be used as a data input to completing an analysis of configuration alternatives (e.g., Level 2) such as: Make-to-Stock or Make-To-Order. SCOR is used to describe, measure, and evaluate supply chains in support of strategic planning and continuous improvement. However, the SCOR model does not attempt to describe every business process or every activity within the supply chain (Poluha, 2007). The excluded components are: marketing and sales (i.e. creation of demand), research and technology, product development and some areas of post-delivery customer service. Furthermore, there are few analytical tools for cause-effect analysis and problem solving at the macro-level and inadequate tools to focus on executing projects identified by the SCOR efforts (Recker and Bolstorff, 2003).

### 2.2.3 Value Stream Mapping (VSM)

Value stream is a collection of all actions value added as well as non-value added that are required to bring a product or a group of products that use the same resources through the

main flows, from raw material to the hands of customers .VSM was initially developed in 1995 with an underlying rationale for the collection and use of the suite of tools as being “to help researchers or practitioners to identify waste in individual value streams and, hence, find an appropriate route to its removal” (Hines and Rich, 1997). The process itself is simple and straightforward. It usually starts with customer delivery and work its way back through the entire process visualizing the process graphically and collecting data along the way (Singh and Sharma, 2009). Finally it results in a single map called “Value stream”, these maps contains data such as cycle time, work-in-process (WIP) levels, quality levels, and equipment performance data (Singh and Sharma, 2009). VSM helps to visualize the current state of the process activities and guides towards the future desire state. Unlike most process mapping techniques that often only document the basic product flow, VSM also documents the flow of information within the system. Where the materials are stored (raw materials and WIP) and what triggers the movement of material from one process to the next are key pieces of information. VSM is about eliminating waste wherever it is.

Value Stream Mapping is a communication tool, a business planning tool, and a tool to manage change process. The first step is to select a product family, then to draw the current state, which is done by gathering information on the shop floor. This provides the information needed to map a future state. The final step is to prepare and begin actively using an implementation plan that describes, on one page, how to plan to achieve the future state (Lasa et al., 2008). However as with any tool, it has limits. VSM was developed and popularised in the automotive industry. Automotive plants are highly focused factories with a narrow family of products for a few customers. VSM works well in these situations. In high variety and low volume factories, VSM is cumbersome and unrealistic (Lee and

Snyder, 2006). Moreover, many VSM symbols correspond to specific Toyota techniques. This may lead the user to employ these techniques even when they are inappropriate (Lee and Snyder, 2006). Overcoming the influence of symbols requires broad knowledge and awareness on the part of users.

### **2.3 Comparison of supply chain modelling tools**

In order to compare and select the supply chain modelling tools for constructing a lean supply chain, the framework from Luo and Tung (1999) are used to evaluate the modelling methods and generate selection procedures. Luo and Tung (1999) propose five following steps for evaluating and selecting business process modelling.

1. Identification of modelling objectives
2. Identification of required perspectives and desired characteristics
3. Identification of alternative modelling methods
4. Evaluation of methods based on required perspectives and characteristics
5. Selection of the appropriate method

The process steps suggest that in each modelling technique, objectives, characteristics and perspectives must be determined. The selection process should be a reconciliation of the required perspectives and characteristics imposed by the modelling objectives and the modelling methods with such requirements. The three constructs, namely objectives, characteristics and perspectives of each modelling methods are discussed in Table 1.

**Table 1: Comparison of supply chain modelling tools**

	<b>IDEF</b>	<b>SCOR Model</b>	<b>VSM</b>
<b>Model objectives:</b>			
Communication	It enhances communication between systems analysts, developers and users through ease of learning and its emphasis on hierarchical exposition of detail	It supports communication among supply chain partners and to improve the effectiveness of supply chain management and related supply chain improvement activities.	It provides clear and concise communications between management and shop floor teams about lean expectations and about the actual material and information flow.
Analysis	It Assists the modeller in identifying what functions are performed, what is needed to perform those functions, what the current system does right, and what the current system does wrong.	It describes, measure, and evaluates the supply chain. It also supports strategic planning and encourages continual improvement of the chain.	It identifies, demonstrates wastes in individual value streams and hence finds appropriate route to its removal.
Control	It describes what a system does, what controls it, what things it works on, what means it uses to perform its functions, and what it produces	It contains standard descriptions of management process, a framework of relationships among the standard processes, standard metrics, management practices and standard alignment to features and functionality.	It consists of everything including the non-value added activities and provides a pictorial view of what elements of the process the customer is willing to pay for.
<b>Characteristics:</b>			
Formality	Diagrams based upon very simple box and arrow graphics. Gradual exposition of detail, featuring a hierarchy with major functions at the top and successive levels of sub-functions revealing well-bounded detail breakout.	It provides a standard format to facilitate communication. It is a useful tool for the upper management of a firm to design and reconfigure its supply chain to achieve desired performance.	It provides a standard format for describing about manufacturing processes and lean concepts.
Scalability	It represents graphically a wide variety of business, manufacturing and other types of enterprise operations to any level of detail. Focusing mainly in a single business.	Using process modelling building blocks, the model can be used to describe supply chains that are very simple or very complex using a common set of definitions. Disparate industries can be linked to describe the depth and breadth of virtually any supply chain.	It can apply into a wide variety of business focusing on lean improvements.
Ease of use	It is easy to learn and use.	It is highly structured and requires detailed analysis of a series of integrated process. As a result, the modellers require training on the modelling technique.	Even though it is simple and straightforward, the modellers require training on symbols and mapping techniques. They also need training on the lean elements that the symbols represent.

	<b>IDEF</b>	<b>SCOR Model</b>	<b>VSM</b>
<b>Perspectives:</b>			
The object perspective	It consists of a hierarchical series of diagrams, text, and glossary cross-referenced to each other. The two primary modelling components are functions (represented on a diagram by boxes) and the data and objects that inter-relate those functions represented by arrows).	A process framework allowing end-to-end descriptions of work, material, and information flows in supply chains. It includes definitions for standard supply chain metrics, definitions for specific activities, standard activity, collections of best practices linked to processes, and a methodology for characterizing and improving supply chains.	It consists of data such as cycle time, WIP levels, quality levels, and equipment performance data, the relationships between the manufacturing processes and the controls used to manage these processes (production scheduling and production information) and etc. It also documents the flow of information within the system.
The activity perspective			
The role perspective			

There are several benefits and limitations of each modelling method in constructing a lean supply chain. IDEF can support a modeller to map the total enterprise and supply chain but pay no attention to non-value-added activities and best practices. Whereas SCOR provides a comprehensive technique to map the supply chain, support continuous improvement, provide best practices and key performance metrics. Nevertheless it does not aim to eliminate the wastes in the chain. Regarding to the characteristics of lean supply chain in section 2.1, to identify roots of non-value added activities, it seems the VSM technique is the most appropriate modelling method to configure a lean supply chain. Therefore, this modelling technique is used in the next section to apply in a case study in order to evaluate how the tool is put into practice.

### **3. A CASE STUDY APPLICATION**

This section presents the case study application of the selected modelling tool in a plating company in Singapore and presents the analysis and discussion of the application.

### **3.1 Background**

The case company is a manufacturing company in Singapore. The company specialises in surface treatment and finished processes for various industries and applications like Aerospace, Domestic Appliances, Optical, Medical, Telecommunications and Semiconductors. In the past years, the company's business has expanded rapidly. This led to the set up of a second plant, specialising in chrome, nickel and cadmium plating in support of aviation maintenance, repair and overhaul (MRO) services.

The company is expecting strong business growth in the coming years. As part of its business strategy, the company plans to improve its operational efficiency on their manufacturing and supply chain processes in order to improve the cycle time and capacity of their plants. Therefore, the main purpose of this study is to assist the company in assessing their current operational efficiency and to identify improvement opportunities within the company and its supply chain. The outcomes will be the operational efficiency improvement expected to enable the company to realise the following goals:

- Reduced operating costs
- Better utilisation of manpower
- Shortened cycle times
- Streamlined manufacturing and supply chain processes with its suppliers and customers
- Long-term quality improvement programmes

### **3.2 Application**

To achieve the purpose of the project, several modelling tools were considered including IDEF, SCOR model and VSM. After the consideration regarding to the discussion in

Section 2, VSM was selected to map the company's processes in order to adopt lean techniques for its enterprise. Therefore, the scope of the study covers the value stream mapping (VSM) and analysis of the company's manufacturing and supply chain operations at one of their plants in the west of Singapore (West Plant). Key lean techniques for the company's processes are identified and proposed. In the process of the study, lean management knowledge has been imparted to the company's project team, in the form of:

1. Facilitation of the company's project team to develop the value stream map for the West Plant's operations.
2. Technical expertise and support on lean Management techniques and methodology.
3. Identification and analysis of lean techniques suitable for the company and supply chain processes.
4. Prioritisation and development of lean implementation roadmap.

The first stage of the study involves the introduction of lean and value stream mapping in terms of lean culture, creating a lean value stream and other lean techniques such as 5S, Pokayoke, JIT/Zero Inventory, Kanban Pull System, Milk Run, Takt Time, Heijunka, Value Stream Mapping and etc. which helps the development of As-Is and To-Be Lean Value Stream maps for the company.

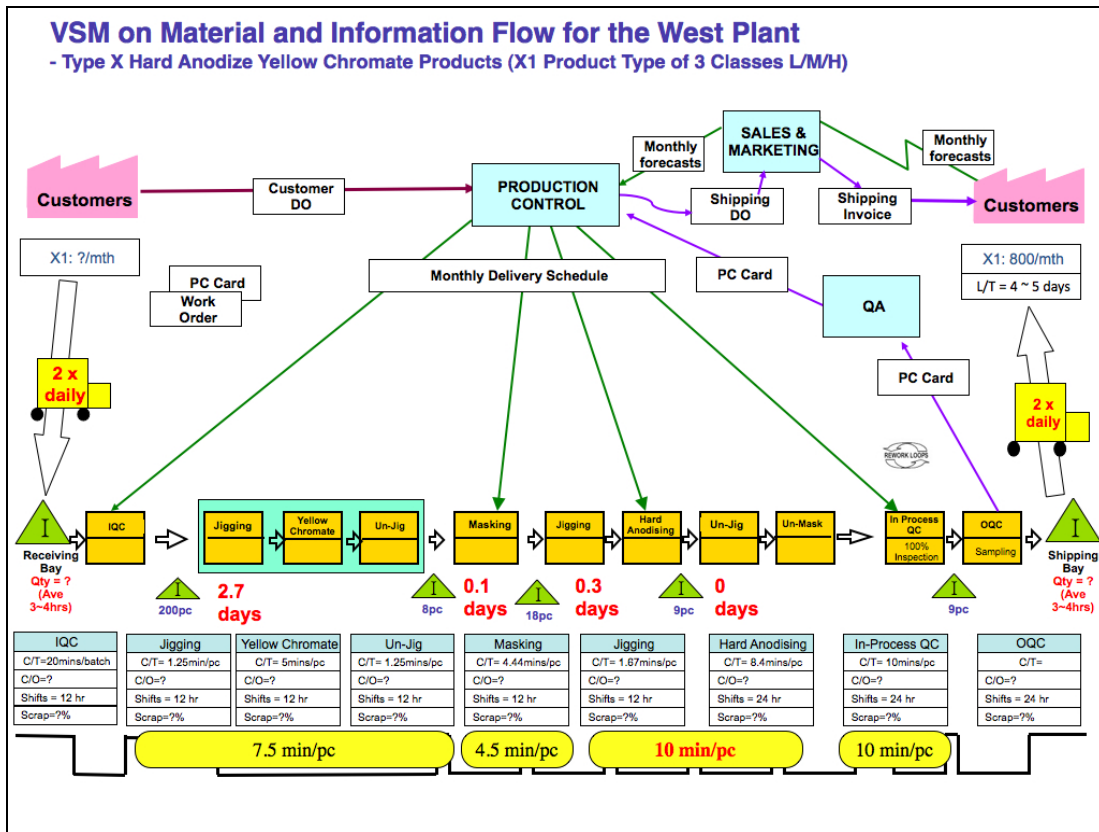
The next stage is the mapping of the As-Is VSM maps and lean opportunities analysis. This stage involves the interview of the key relevant staffs to understand the company's business environment, challenges and goals. Performance goals are identified and set. Thereafter, the current manufacturing operations and business processes are assessed and the high level current process and information flow are mapped. Finally, a detailed As-Is value stream is mapped with the input from the company's project team. All types of

'wastes' and weak links across the value stream are identified. Through the analysis of the As-Is value stream, the project team gains a clear understanding of the company's current manufacturing and business dynamics. All lean improvement opportunities identified are then analysed.

Finally, the project team decides how the business processes should look to reduce the overall cycle time. The team then undergoes the re-configuration exercise to design the To-Be value stream map. As a wide variety of opportunities have been identified, the team prioritises them according to the implementation time frame, cost, impact and benefit. Subsequently, the lean implementation roadmap is developed based on the analysis of the prioritisation.

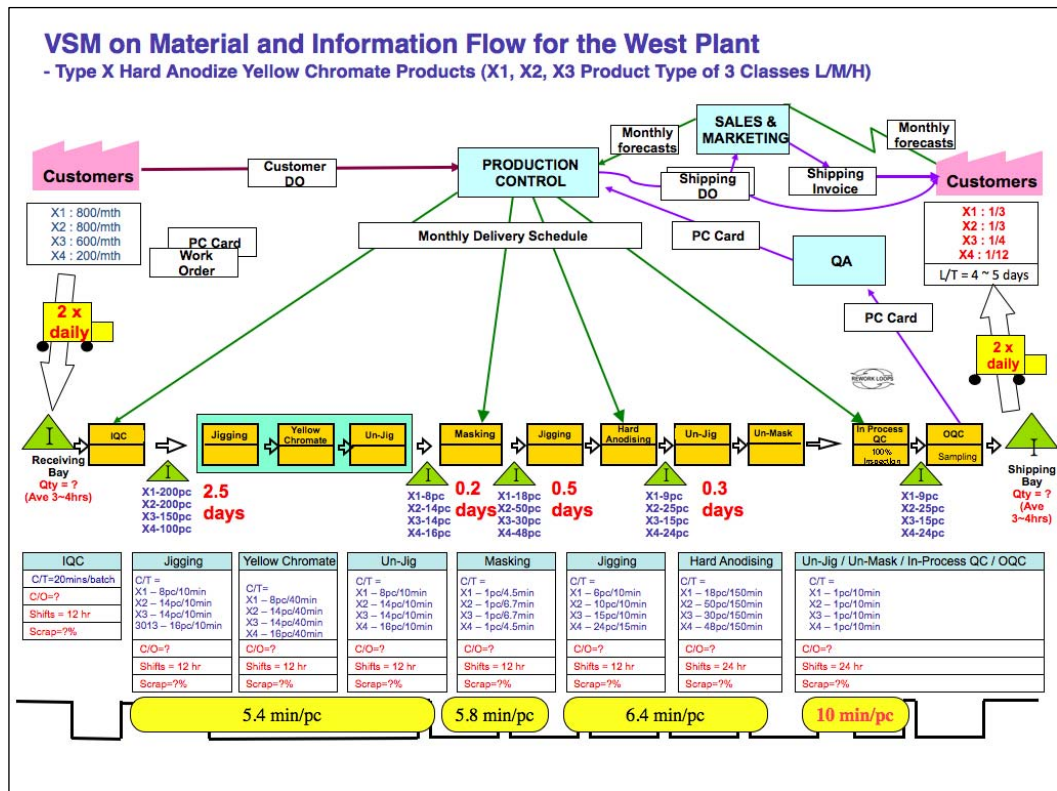
### **3.3 Results**

Type X Hard Anodize Yellow Chromate Products were selected as the product family/group to construct the Value Stream Map (VSM). This product family consists of 4 product types, namely X1, X2, X3, and X4. With the inputs from the company's team, the As-Is VSM was constructed. Figure 2 shows the As-Is Value Stream Map for Product Type, X1. A total of 4 As-Is VSM were constructed for each of the product types in the product family identified and discussed.



**Figure 2 As-Is Value Stream Map for Product Type X1**

Subsequently, these 4 As-Is VSM were combined into one map to represent the value stream of the Type X product family. Figure 3 shows this As-Is Value Stream Map. This is achieved by proportioning the values for each product type against their production volume ratios.



**Figure 3 As-Is Value Stream Map for Type X Product Family**

Verification was conducted on the value stream maps constructed with the company's team. Assumptions taken were as follows:

1. **Yellow Chromate Process.** The yellow chromate is taken up about 21% of the total yellow chromate capacity. However, it can be loaded in the parts anytime when required. Thus, it is assumed that this product family has full capacity of the Yellow Chromate process.
2. **Masking Process.** There are total of 15 masking staffs. Out of which 30% of the staffs are involved in the 4 part numbers listed in the study. Thus, it is "dedicated" masker for this product family is 4.5 staffs. Process time of the Masking stage is reduced by a factor of 4.5.
3. **Hard Anodizing Process.** There are 2 hard anodizing tanks that the 4 selected part numbers in the study will take up about 17% of the total loads. However, it can be given priority to these 4 part numbers and when there are sufficient parts to make

up one load or to plan to process the parts in the next loading. Thus, similar to Yellow Chromate, this product family has full capacity of the Hard Anodizing process.

Actual total process time of the un-jig, un-mask, in-process QC and OQC could not be verified. But it was generally agreed to be less than 5min as opposed to the 10min specified earlier. Thus, adjustment was made to the As-Is VSM in Figure 3 and the Final As-Is VSM is presented in Figure 4.

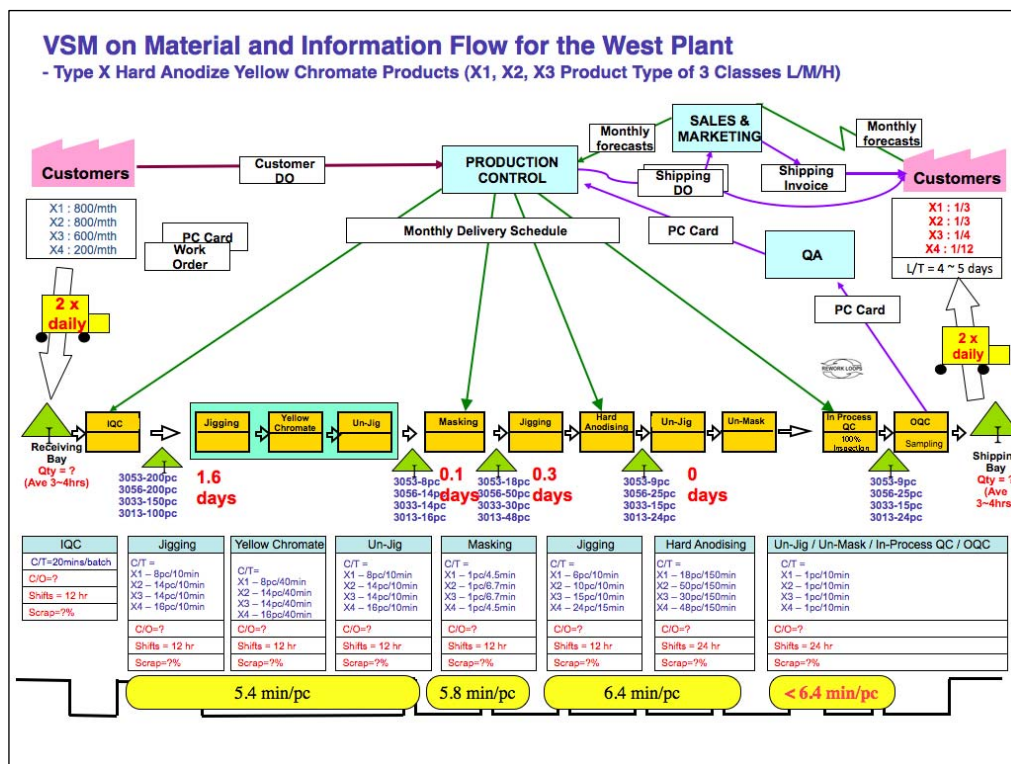


Figure 4 Final As-Is Value Stream Map for the Type X Product Family

### 3.4 Analysis and Discussions

Based on the As-Is VSM diagram shown in Figure 4, the bottleneck for Type X Hard Anodize Yellow Chromate Products' value adding process chain is Hard Anodizing (according to the per unit processing time calculation). Since the Type X Hard Anodize Yellow Chromate Products have higher processing priority ranking than other products, the

4 product types (X1, X2, X3, X4) are processed as soon as they arrive, with minimal work in process (WIP) inventory and non-value adding time at the various inventory points. However, actual case gathered reveals that the waiting time for other parts may be severely affected by this priority rule set. The extent of this impact cannot be ascertained by the VSM technique employed.

In general, the prioritisation rule which applies to a particular product family/group will have a positive influence on the turnaround time of that group or family through the minimising of waiting time at each inventory for that group. However, this also means that other customer orders will need to be pushed back to accommodate this group of parts. Therefore, the set of prioritisation rules will play a key role in managing the overall turnaround time performance of the company. It should be exercised with caution the company do not over compensate or compromise the orders received.

Six potential improvement areas are identified. They are,

### **1. Inventory Holding Time at Receiving**

Pushing inventory out of shop floor does not solve the problem as the parts are already in the system. From Figure 4, the bulk of the waiting time is incurred at the IQC point which is the parts receiving point. This means that in general, parts are sitting around on the company's site for at least 1.5 day before they are being processed. This shows that the parts arrival from the customer are not paced or managed. This is a key area to significantly reduce the turnaround time for parts.

## **2. Inventory Holding Time at Delivery**

If finished parts missed the daily delivery schedule, it will stay for an additional day in the system. Thus, at least 1 day can be removed from the system through more timely or in-sync production to the delivery timings.

## **3. Bottleneck Resources**

Given 100% priority for this product family in Yellow Chromate & Hard Anodizing process, bottleneck process time is at least 6.5 min/pc or more at the Hard Anodizing Process. However, with the Hard Anodizing Process being a shared process required by other product family, the parts prioritization process will play a key role in the management of the overall turnaround time of all parts.

## **4. Product Dispatching based On Capacity Balancing**

Each product family sent to the company has its own set of processing requirements and process flow steps. The setup times and setup costs are often not significant because the jobs are primary manual based and labour intensive. Thus in such a system, an alternating schedule will be more efficient than one with long runs of an identical job.

A proper mix of product families (with different processing requirements and process flow steps) to be released into the shopfloor will achieve a balanced utilisation at the Yellow Chromate, Masking and Hard Anodizing stations. For example, product families with Yellow Chromate process and Hard Anodizing process can be released into the shop floor together as both product families can be processed independently without adverse effects on each other. However, if a product family requiring both processes is released, the bottleneck in one station will affect the overall throughput of the parts.

## **5. Manpower Reallocation/ Reassignment of Responsibility**

The value adding processes in the company are highly customisable as their customer products come in any shapes and sizes. Therefore many skilled workers are required to ensure the general-purpose equipment can fulfil all customer orders. The concept of production automation in this case has limited application except for those high volume product families. However the concept of “business process” automation is applicable for the company to streamline the translation of customer order into PC Card and work order. This will relieve the production staff from the non value-adding task of generating paper trail, which the customers do not concern about. The same staff can now be reassigned to manage only the exceptional cases that may arise in the process as well as other responsibilities such as capacity profiling etc.

## **6. Capacity Expansion**

Production capacity expansion can be realised in many forms such as purchasing additional equipments, upgrading existing equipments, allocating more manpower resources and etc. These are a few options a company can explore to increase its physical capacity. However, these options often entail large capital investment, high depreciation cost, and also the risk of under-utilisation of asset due to customer order's fluctuation.

Some of the commonly used reference guidelines to determine the viability of adding or upgrading an equipment are the utilisation rate of equipment after considering scheduled maintenance downtime, minimal interruption to existing production processes, and low risk of equipment obsolescent in near future.

In view of these potential areas for improvement, 5 probable Lean Initiatives are proposed.

They are,

1. Pace Part Arrival from Customer
2. Pace Production with Delivery
3. Production Planning tool for Takt loading
4. Kanban pull for synchronised production
5. Part Prioritisation Matrix to achieve Heijunka

Figure 5 shows the To-Be VSM for the company.

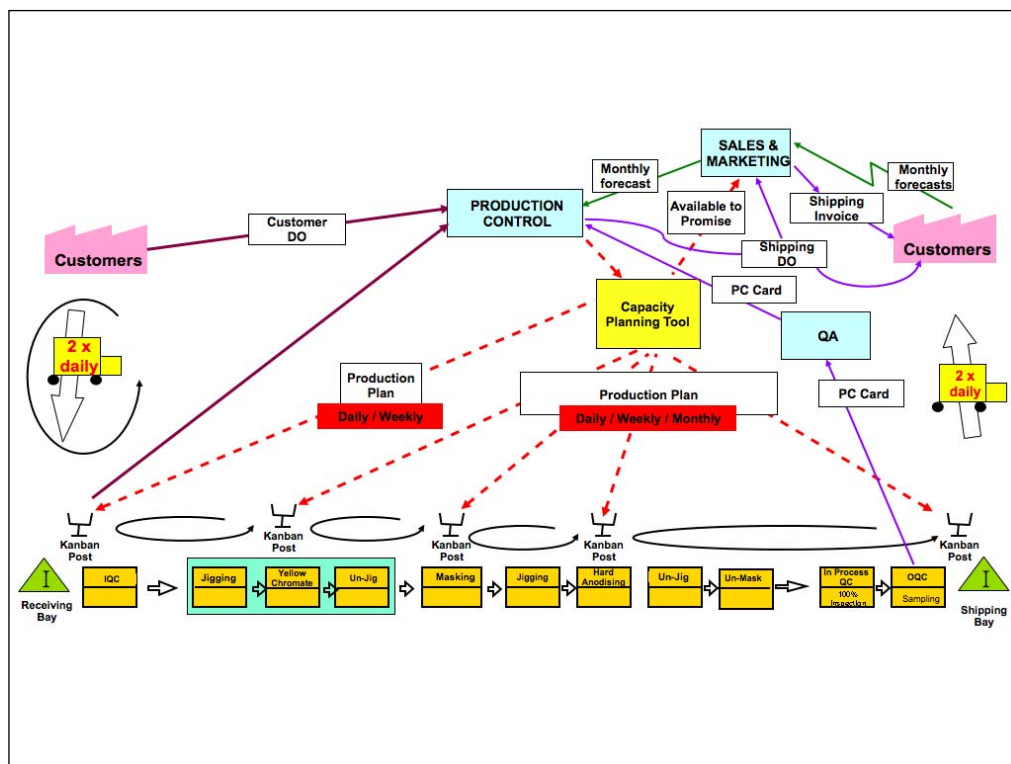


Figure 5 To-Be Value Stream Map

### 3.5 Lean Supply Chain Design

From the list of Lean initiatives identified, only the first initiative deals with lean supply chain design and management while the other four deals with the design and management of the manufacturing facility. As such, this section will discuss about the former, which is to pace parts arrivals from customer.

From the VSM analysis, it is evident that a majority of the cycle time for the parts is spent at the receiving bay. The average cycle time for this product family is 3-4 days. With an average holding time of close to 2 days at the receiving bay (see Figure 4), the non-value added time for this process is at least 50% of the system's end-to-end lead-time. Thus, this poses a great opportunity for a dramatic cycle time improvement on the company's operations through a lean supply chain design.

Instead of receiving parts based upon the customer's push, a lean design would be a pull model to pace parts receives between the company and its customer. Kanban signals to couple with TAKT time implementation for the system can be used to pace the parts arrival at the receiving bay. Operationally, this makes perfect sense and the total cycle time can be drastically reduced via this effort. However, such action do not make any business sense to the company as it would results in the company losing business from this customer if they do not receive the parts at their customer's pace. The reason for this is that the company can secure the business if they just receive the parts regardless of their capacity. If the parts are already sitting on the company's end, it's very unlikely that the customer will withdraw it even if the company fails to deliver on time.

Proposing to move these parts to customers' site holds the risk that these jobs might eventually be awarded to another company since the customer might think that the company do not have the required capacity to complete the order if the company refuse to accept the order to their site. Such supply chain issues cannot be addressed via the VSM technique discussed because the company and its customer are two separate business entities. Despite the potential improvement to the system as a whole, this design will not

be feasible unless the company has established a long-term collaboration relationship with its customer to achieve the best value for their customer's end customers. Even if the trust is there, to synchronise and pace the production of two separate business entities are difficult because it requires a design to tightly couple these entities to operate as one business. This is also the key challenge of adopting VSM techniques for supply chain design, as many supply chain designs involve the organisation of separate business entities in a chain, each looking at optimising their own performance rather than for the good of the supply chain as a whole. The difficulty is in getting people to make that mental change to work towards common goals instead of individual, and sometimes conflicting, goals.

VSM technique is a very good tool to create a big picture of a system to identify the bottleneck and slack for lead time and cost reduction. It can be built as a very high level look that provides a conceptual understanding of the supply chain's structure and key interactions. The rest of the lean techniques can then be applied to design the new system. For a single site like a manufacturing plant, all processes in the system are owned by the company. Thus, it makes the redesign and implementation of appropriate lean techniques easy and manageable. In a supply chain set up where it consists of many different business entities, the VSM technique can still identify the bottleneck or slack in the system. However, the implementation of the proposed solution will depend on the economic strength and power of the company using this technique. Whether in the role of supplier or customer, a company rarely has any real visibility into its trading partners' activities. Even though a customer and supplier may meet on a regular basis, they do not look at the details of each other's processes. In addition, each company has other customers and suppliers besides the ones in a given supply chain. Very often, the chain master would be the most ideal company to use this technique to shape and design the supply chain where it sits in.

The chain master should also provide lean awareness training to the suppliers. For this case study, the company is not in the position to influence the supply chain design. Thus, rendering the VSM technique is less effective for such purpose.

#### **4. CONCLUSIONS**

This paper contributes to the knowledge on mapping tools for constructing a lean supply chain. It provides an evaluation of existing mapping tools for change processes within the organisation or a supply chain. The conclusions of this research are useful for future practitioners, so that they may bear in mind the different aspects of planning projects for redesigning supply chain system by using a visual tool to diagnose and review their supply chains. On the other hand, these conclusions can also be useful for the academic field in order to enhance the theory of mapping tools for constructing a lean supply chain.

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