Sustaining Supply Chain Operations through Lean Manufacturing

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Abstract

Purpose – The study aims to report a case study in a Thai Electronics Manufacturing deploying a lean manufacturing approach, and to discuss the value gained in their supply chain operations. These experiences can be adapted by others for design, redesign, and problem shooting when analyzing the performance of supply chain operations.

Approach – The paper is based on actual activities in a case study. This paper begins by reviewing the relevant literature on supply chain operations and supply chain uncertainty, and then reviews lean manufacturing implementation. The literature review helps to validate the case study, which is a challenge of high mix, low volume and unstable demand manufacturing. The paper also describes two major techniques, continuous improvement and Kaizen activities, and then focuses on the seven types of waste. It also indicates the practical obstacles to the implementation.

Findings – The analysis of the case study shows that the major critical successful factor in implementation is the commitment from top management and actual involvement of individual operators in the production line, who have the same goal to enhance the supply chain activities. The technical aspect has less impact if planned properly.

Value – This paper explains the actual activities of lean manufacturing implementation in details. The first approach is to educate and convince people about continuous improvement activity

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to gain their cooperation. After the employees are willing to take part and act independently, the company can gain continuously. Secondly, the 7-waste perspective of production flexibility is gained. However, resistance to change, the amount of data, and the practicalities of waste reduction are limitations in implementation.
Key Words – Lean Manufacturing, Industrial and Operational Management, Synergy, Kaizen Activity, Electronics Supply Chain
Paper type – Case Study

Introduction

Today's diverse marketplace presents a challenge to supply chain operations in that different solutions are required for a range of customer requirements and sustainable supply chain advantages. The advantage of developing sustainable supply chains is that it achieves the collaboration and communication capabilities of vertically integrated firms (i.e., hierarchies) while maintaining the flexibility and responsiveness capabilities of market-oriented governance structures.

Significant interest has been shown in recent years in the concepts of lean manufacturing (Aitken et al, 2002). Lean manufacturing can be employed as a strategy for value leadership and goes well beyond cost reduction (Womack, et al., 2007). Naylor, et al. (1999) described the use of lean manufacturing and the agility paradigm, which have the ability to integrate the strategies of the supply chain, especially considering market knowledge and the positioning of the decoupling point as agile manufacturing is best suited to satisfy uneven demand. Lean manufacturing requires a level schedule and also focuses on the cost performance outcome of the operation, which must be driven by lean manufacturing approach to be competitive (Hallgren & Olhager, 2009).

In the electronics supply chains, the original know-how came from, for example, the United States but the production base is in Asia such as Thailand and China. The companies have transferred both technology competiveness and knowledge of know-how to the production site. Many companies agree about the lean thinking philosophy and lean manufacturing methods and principles could lead to a successful lean organization (Shetty, et al., 2010). In this paper the definition of both paradigms is provided by Naylor et al (1999) as follows: ***Agility*** means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile marketplace. ***Leanness*** means developing a value stream to eliminate all waste, including time, and to enable a level schedule.

Lean manufacturing approach works well where demand is relatively stable and hence predictable and where product variety is relatively low (Christopher, 2000). However, an agility paradigm can be applied more directly to mass customization and can be rather quick to respond (Flumerfelt, et al., 2012; Tsai, et al, 2012). The supplier must provide high quality products, on time and at a reasonable price to all customers. The relationship between customers and suppliers is handled and processed through the supply chain. It is possible that providers are often the manufacturer. Global manufacturers need to be optimal by using a lean manufacturing approach as they have to focus on cost reduction. Cost is a major factor of competitiveness,

and no business can survive without profit., The lean manufacturing concept can be applied to supply chain operation, not only on the production floor, such as the quotation process, which applies the lean manufacturing principle to help reduce the total cycle time (Buzby, et al., 2002). Moreover, lean manufacturing can generate synergy such as reducing set-up time, reducing prototype development time, improving space utilization, increasing flexibility in assembly work and enhancing management happiness with successful implementation throughout the firm (Hilletofth & Eriksson, 2011).

In the next section, we begin by introducing the background information of the case company. Section 3 then reviews the literature on lean manufacturing activities in supply chain operations, uncovering the key gaps that we address with the following case study. We use the result of case study analysis for discussion. Finally, we suggest some future research opportunities and conclude the paper.

Electronic Manufacturing Service in Thailand

An Electronics Manufacturing Service (EMS) industry is a factory that provides servicing in the full turnkey of all electronics manufacturing, such as PCBA fabrication and box assembly, and is also involved in component design and the sourcing of resources for all services and activities. Mostly, EMSs network their operations to connect with suppliers and customers to improve efficiency and capacity and to raise operational capability in key markets. Some companies have operated their business as an original equipment manufacturer (OEM) by producing products under their customer's original trademark. The original technologies have been provided by the customer to their contract manufacturer to produce products as required. Therefore, a close relationship between the EMS and the supplier is needed to carry out their operations. In Thailand, there are about 900 electronics factories with 7.2 Billion USD capital investment and over 200,000 people working in this sector, including the EMS business (Department of Industrial Works, 2012)

In cases of complicated engineering and the precision manufacturing of electronic products, the industry employs a combination of high and low volume production that reflects demand (Gill, et al., 2008). Some products are in high demand, such as PCBs. High quality products are strictly monitored in the production process while other products are produced in larger volumes. For example, the production line of SMT produces printed circuit boards which support many internal and external customers. As a result of the company practices, strict quality and manufacturing process disciplines in all aspects of its operations are carried out, as well as offering customers a cost advantage with a steady value proposition for manufacturing highly complex products. All staffs are trained in Six Sigma and Kaizen standards, and focus on continuous improvement in all functional areas. They have had ISO 9002 and ISO 13485 certifications, and the factory is TL 9000 and TS 16949-certified. The company is structured as a "factory in a mini-factory" which allows the possibility of establishing processes and manufacturing operations to a single client or controlling a particular product. All production lines are offered full IP security (Intellectual Property Protection).

Lean Manufacturing Activities in Supply Chain Operations

In basic production practice, achievement is a function of productivity, quality, cost, delivery, safety and environment, and morale, shown as the abbreviation PQCDSM. Hence, the production focus in optimizing the process of competitive products is to produce products of the highest quality, the lowest cost, and with the shortest delivery lead time. As described, the lean system's foundation is stability and standardization, helped by the just-in-time delivery of materials. The key objective has a focus on customers by the involvement of the supply chain members. Good examples of Toyota's system's effectiveness in lean manufacturing include the "thinking ways" and the "continual reinforcement of core concepts" (Dennis, 2007; Cudney & Elrod, 2010; Liker & Hoseus, 2010). Team members must be motivated, flexible and continuously seeking to improve the gaps. Big changes are not required for each gap improvement; however, the continual improvement of the mind set of team members has to be nurtured. Therefore, customer focus is the major success in business competition.

The reduction of waste is a matter of concern to customers because they are not willing to pay for it (Womack, et al, 2007). Seven types of waste in production include motion, delay or waiting, transportation, correction or rework or defect, over-processing, inventory, overproduction. There are also suggestions on the lean production principle. The process of implementing lean manufacturing techniques has five-steps and starts from the customer's point of view of specified value; then a value stream map is created, and then the process adds value and transfers the value to the next upstream activity. The next focus is on the steadiness of the lean system. Firstly, 5S supports the operation of all standard features and improves the basic processes that can achieve basic process stability (Dennis, 2007), for instance, the three main standard element baselines in the operation are the Takt time, the work sequence and In-process inventory. Waste elimination in Kaizen activities is achieved by creating a standard process. In addition, other fundamental lean operation tools include flexible workers, self-directed teams, a focus on continuous improvement (CI), mistake proofing (Poka-Yoke), and preventive maintenance programs (Trent, 2008).

The literature suggests that superior business performance is achieved through competitive advantages by developing business capabilities that provide value-added activities to an end-user in unique ways or at lower prices than competitors [6]. Providing value-added activities in unique and low-cost ways require anticipating customer demand and responding to changes in the demand faster than competitors (Stalk et al, 1999). Independent firms can leverage each others' capabilities to achieve competitive advantage for the entire supply chain. The literature refers to the leverage of capabilities in a supply chain as an outcome of SCI. To explain how companies create capabilities, the Resource-Based View theory says that firms must invest resources in improving business processes (Stank et al, 2005). These include, but are not limited to, demand management, new product development, customer relationship management, inventory management, evaluation capabilities.

Additionally, information is needed to use the principles of lean production on the shop floor as well as in production as inventory levels, logistics, production control and

workshop scheduling systems impact the whole performance (DETTY & YINGLING, 2000).The visual indicator development and the Lean Thinking Management Wheel models help to assess lean thinking manufacturing initiatives uniquely and also have great potential to be used industry wide (Shetty, et al., 2010). Lean manufacturing can be measured in terms of non financial performance, such as in quality improvement (Fullerton & Wempe, 2009). The basic concept of lean manufacturing needs to be applied rather than other aspects of the approach, for instance, a whole-life value and waste identification to prevent overlooking some aspects of concern ((Jørgensen & Emmitt, 2008) and(Bhasin, 2011)). In a general documentation system, for example a quality manual, procedures and work instructions affected by the lean thinking implementation, and also principles and tools in lean manufacturing, for instance, value stream mapping, lean metrics, and 5S have been more formalised into ISO 9001 documents (Chiarini, 2011).

Consequently, the required information must be balanced. Standards are very useful in the production process. For example, the process stability has high repeatability for PQCDSM performance on output. Furthermore, Just-in-time manufacturing (JIT) determines that the production is processed optimally, with the right quantity at the right time. Anything else is wasteful. Conventional mass production often uses a push production system: orders start from meeting customer requirements which are incorporated into the production stream through to the finished goods for sale. The JIT concept has enabled significant achievements in JIT production and improves businesses competitiveness through the adaptation in accordance with an organization's environmental changes by sharing organizational values, involvement, opportunities in potential skills and coordinated flows in the supply chain and logistics. The achievements in terms of higher levels of productivity while minimizing the related costs for performing the logistics activities are considered as the features of a proficient firm (Danese et al, 2012). Fundamental concepts are integrated in a successful JIT program. First, so-called "no blame" concept is implemented, based on the belief that nobody comes to work to intentionally do a poor quality job. Second, the "triple role" concept indicates that everybody can be considered as operating in one of three roles, either as a customer, a manufacturer or a supplier (Hutchins, 1999). For the case of Kaizen activity, it is the key satisfaction of the team to add significant value in processing to ensure of solid continuous improvement (Trent, 2008). Many participants are required in a Kaizen activity, which needs company supports on proper basic knowledge, and some rewards are needed to reinforce and drive the activity cycle to continue moving forward. The basic rule of thumb generally suggested in the Kaizen concept is to focus on quantity first and then quality.

Lean manufacturing is in direct opposition with conventional production approaches characterized by utilization of a variety of approaches such as economic order quantities, high capacity utilization, and high inventory. In changing from a traditional manufacturing environment to one of lean production, cultural issues indeed emerge quickly, as well as resistance to change. It is important to notice lean manufacturing techniques and concepts represent one way operations in manufacturing are changing their operations culture toward efficiency and continuous improvement.

Schein's (1990) distinguishes culture into three levels: artifacts or what an observer can see, values or what people talk about, and the underlying assumptions of these

values or what employees really think or believe. Schein's culture model is important for this research, not only to understand the case organizational culture, but also to understand why implementing lean is not so easy. Schein's culture model explains that implementing artifacts, or in some cases, lean principles, will not work. Artifacts are only one of three levels of culture model. To successfully implement lean manufacturing, all three levels of culture have to be penetrated by lean thinking within the organization.

Kaizen activity is one of key elements towards successful lean manufacturing. A Kaizen lean production culture attempts to constantly improve the supply chain operations and production process. Significant changes could be made by reengineering the production process, which may be much more expensive (Santos, et al., 2006). It is important to note the organizational culture, to build key relationships with important business executives within the company, to make sure there is complete alignment of the company's supply chain needs with procurement teams who are supporting those acquisitions (Leong and Teh, 2012). It is also important to note that involvement in kaizen activities could develop new knowledge, skills, and abilities that may be applied to subsequent problem-solving tasks. Kaizen creates an environment and organizational culture which compels the workforce to constantly improve the company's products and internal processes, even during the time period of no any apparent external threat.

Education and training are essential to develop such an organizational culture and to create a mind-set in the workforce which continually identifies and finds solutions for manufacturing problems. In fact, a high level of involvement of blue-collar workers can only be achieved through a mixture of on-the-job and off-the-job training that goes far beyond the acquisition of basic knowledge of electronics and mechanics.

When there are changes to an activity, there are likely to be barriers, as illustrated by Rubrich (2004). Ten reasons for failure have been identified when a company tries to implement the Lean Manufacturing concept: lack of top down management support; lack of communication; lack of middle management/supervisor buy-in; not understanding that this is about your people; lack of customer focus; lack of improvement measurements; lack of lean leadership; people measures are not aligned with a world class enterprise; using Kaizen events as the sole improvement mechanism, and bonus pay systems where the only measure is company profitability.

It is necessary to prevent the cost of any serious mistake that occurs from a lack of communication in the organization. The communication of change is required for the organization to change successfully as a good strategy has to be prepared in order to communicate the point of change well with unequivocal information to all concerned people (Palmer, et al., 2009). Therefore, the change leader is the key player in the change communication to provide the details of change and to inform and track the right people. Face-to face communication, interpersonal interaction, is the most effective way (Gilley, 2005). The silent rules, which are unspoken and accepted existing working practices, are another barrier to change. Such rules seem to have unusual cultural characteristics in any change process especially for rule-makers. It is possibly damaging if the company is not aware of them and does not control them (Wilson, 2010), for example, an adaptation to lean manufacturing is instigated by employees; however, managers feel uncomfortable about the change having been pressured into it by staff (Abdulmaleka & Rajgopal, 2007).

The rule 10-80-10 illustrates a performance level of response to change in an organization where the middle management sometimes acts as a roadblock in the process of change (Rubrich, 2004) as shown the summary inTable1. The difficulty in change comes from poor communication to the people who are in the majority (80%) group which is sitting on the fence. These people can be a roadblock if they are not convinced by a proposed change. Thus, it is essential to communicate effectively with the critical group of employees, and it is the key to success in business change to direct a company towards world class lean manufacturing.

% of Company	Performance Level	What To Do
10%	Top performers, hard workers, will always do the right things	Reward
80%	Solid performers, the silent majority, must support a change	Communicate, Communicate, Communicate
10%	Unconcerned about the company's future, don't want to change, say we've always done it this way, no participation, no ownership.	The company's future is at risk with these people as part of the organization.

Table 1: Summary of the 10-80-10 Rules for Organizational Change

Several lean manufacturing benefits to the supply chain operation include the waste reduction foci and raising the response speed to customers. This also implies that when customer satisfaction is improved, sales demand can rise as well. A business cannot carry a high operating cost, so lean manufacturing is appropriate to assist in the implementation of cost reduction plans. Moreover, the inventory is considered as waste in the lean manufacturing concept (Tompkins, 2006). A key indicator that could measure business performance, which is generally used in business, is the inventory turnover, which is the ratio that determines how many times a company has sold their inventory and replaced it over a given period (INVESTOPEDIA, A Frobes Digital Company, online, 2009). Moreover, waste must be eliminated and should be followed by the reduction of cost from the lean implementation activities, for example, by reducing the space to build a product, enhancing overall manufacturing flexibility, identifying future kaizen workshops, or by ensuring a safer work environment and improving employee morale (Gembutsu, Lean Manufacturing Consultants, 2009). Finally, the supply chain operation needs to align to stay in business. Their competitive advantage can be increased in the global market by applying the lean thinking concept in the business. For example, lean adaptation could bring potential benefits by reducing production lead-time and the work-in-process inventory, as in the study of a large integrated steel mill industry (Abdulmaleka & Rajgopal, 2007).

Conventionally, the benefits of a lean manufacturing approach are focused on cost reduction. Lowering cost can also help a business to be more competitive and to gain more profit. For instance, the production control principles consist of production levelling, the pull production system and time control and management. The result after implementation is an increase in service level and a reduction in flow time which can enhance delivery performance (Slompa, et al., 2009). Lean application can be applied not only in manufacturing industries but also in service industries, such as health care

services. The lean approach using a "one piece flow" concept can save treatment time and increase the number of patients receiving a CT scan (Toussaint & Gerard, 2010). Other implications on the overall value creation along the supply chain are the most important and also avoid the Forrester effect (Webster, 2008).

An EMS Case Study

Details of the case company background are included in Appendix A. Regarding the demand characteristics and the number of products in the case study, there is medium to high volume with the moderate level of product variety so lean manufacturing can be applied by selecting techniques. The case focuses on two lean techniques: continuous improvement and Kaizen activities, and then focuses on the 7-waste. It also indicates the practical obstacles to the activity. The major concern in implementation is the directions from top management to the individual operators in the production line, who have the same goal, in order to sustain the supply chain operations.

Continuous Improvement and Kaizen activities: this case study implemented the continuous improvement and Kaizen activities in two phases: the beginning phase and the sustaining phase. In the beginning period of the case study, the company has been focusing on continuous improvement as a company policy since they have been certified ISO 9001, which requires the existence of an improvement program in their quality policy, such as a continuous improvement committee, a six-sigma training program and other related training packages. They found many difficulties when starting these activities. Basically, the company planned to gain a contribution in continuous improvement activity from their staff level employees; however, it is not enough because there are only 15% of employees in the staff level. Therefore, they need to promote this activity and get a greater contribution from most of their employees. Kaizen activity is the solution to this question. After they promote Kaizen activity, the company is expected to obtain some of the submitted Kaizen reports which would be promoted in the internal quality promotion day event. However, the response rate for the Kaizen activity per headcount was only about 20% and also there was much variation in potential Kaizen activities, which made it difficult to measure the value of the report properly. Regarding continuous improvement, each BU set the performance indicators of their continuous improvement plan by using a Green Belt project approach. It was conducted by the engineering team. Hence, the continuous improvement committee planned to improve the participation rate of employees, especially shop floor staff. They classified their Kaizen project into five categories which are Kaizen-cost, Kaizen-quality, Kaizen-delivery, Kaizen-safety, and Kaizen-others. This standardization helps employees to identify issues affecting their report and clarifies the value of reporting. The company can pinpoint any specific area of the report, such as the cost or delivery, by counting the number of Kaizen reports in each category. The Kaizen-other is the open ended category. Using this standard initially created some problems but the return on the Kaizen-other report was the highest. The submitted reports required some screening at the earlier stage before the continuous improvement manager accepted the report. Nevertheless, the performance on this activity is level but seems more systematic.

Based on the case study, a Kaizen event is a multiple day gathering of a cross functional work group to solve a particular problem in the work flow. Cross functionality of the group helps ensure that new "out of the box" ideas are presented and all aspects of the issue are represented. It is an intense examination of the problem including evaluation of all inputs, outputs and associated constraints. Kaizen is most often used for larger problems though scaled down versions are appropriate at work stations and with small work teams. For example one mill used a Kaizen event to improve the flow of material at a log infeed to a sawmill.

The sustaining phase of these activities in the case study is started by the vision of the top management. The company plans to measure the Kaizen and Continuous Improvement activity performance of each BU. Every BU must include it as a performance measure. However, it is not easy to increase the amount of participation. Many BUs needed to reinforce their qualified report by offering rewards. After that, the results were positive, and they also met their target KPI. The overall reporting performance of the company rose to 35% of the headcount. In the next step, the company tried to integrate the activity with individual employee performance, which is considered as an employee bonus as well.

Based on the case study, two major barriers were identified. First, in the initial period of Kaizen activity, there were some difficulties, such as a lack of support from the BU manager, inadequate report writing skills, and also the lack of incentives or rewards to perform this activity. Second, in the sustaining phase, 100% of employees were required to report on the basic continuous improvement and Kaizen concept, which took some time to return because of the number of qualified continuous improvement and Kaizen reports, and also because they did not officially provide any support in terms of incentive or reward.

The case study gathers some opinions of participating staff on the continuous improvement and Kaizen activity implementation that are from the continuous improvement manager, Production supervisor, Engineer, Planner and BU manager. All of them agree that the continuous improvement and Kaizen activity implementation is a very strong synergy that could drive the company to improve in all areas. The barriers in Kaizen and continuous improvement activity include the company policy and the support from management including time; resources and budget including incentives and rewards, which could be either physical rewards or recognition. Therein forcing of the importance of continuous improvement and Kaizen activities is also important. Some small pop-up rewards can help. This to make sure that people will not lose momentum and the employees are willing to support this activity. In addition, the strength of the company on Kaizen and continuous improvement activity is 'quality by objective' that needs to be obtained from all BUs. This will be embedded in one of their KPIs.

Lastly, it is expected that if the program is successful, all employees will better understand the concept of improvement and keep it in mind. Consequently, the company will grow strongly and enjoy good relations among the team because they have to work together as a team to drive continuous improvement (top-down process) and Kaizen (bottom-up process). It will be useful for a company by gradually achieving quality improvement, cost reduction and enhancing the quality of employees as well as enjoying better customer satisfaction by promoting continuous improvement and Kaizen activities that may attract more customers and are related to customer benefits. Another

gain is it also eliminates the excessive work load for employees so they will find that they can work easier, more comfortably and more enjoyably causing a lower turnover. However, sometimes a continuous improvement project is laden with technical issues. Mostly, engineers will handle continuous improvement related projects such as quality improvement projects, or work improvement projects. They express less concern about any technical aspects dealing with the lean manufacturing.

Since not all employees participate in these activities, companies should encourage them in the concepts of continuous improvement and Kaizen and allow the employees to participate in these activities by having a class or seminar training for existing employees in production and support functions, and by adding the topic of continuous improvement and Kaizen in orientation classes for newcomers. The strong point to achieve the goal is that most operators and engineers have a positive attitude and understanding about the importance of continuous improvement and Kaizen for the company. Furthermore, top management understands and encourages staff to participate in these activities by giving a reward for the best Kaizen project. In addition, their performance level is just a good starting point. They still have a long way to go as the expected benefits include value added and keeping people thinking, rather than just working day-by-day performing repetitive, menial tasks.

Seven-waste analysis activities focus on production: Based on the case study the activities of the 7-waste analysis are illustrated as follows.

Inventory waste: This waste is the hidden waste that impacts a company in terms of the cost of production and overheads, working capital and interest paid. It does not have a not direct impact on the customer. The management will monitor the inventory performance monthly, so in the individual BU the owner assigns duties in each inventory location: the buyers take care of the materials in transit until they are in the company store; production planners take care of semi-finished goods and finished goods, and production supervisors take care of the work order, shop floor raw materials, and also failed materials (MRB). The inventory performance is controlled by the aging of the inventory in each location. Consequently, the control of an aging inventory escalates the inventory monitoring level which is allocated in terms of area responsibility, and, as a result, the inventory is going to be lean. It encourages all participants to focus on their inventory regularly. However, there are some problems in aging control, for example, Sometimes the verification took too long, and in some cases, such as in new cases or new problems that needed to be dealt with by the supplier in quality inquiries. Another example of a problem is WIP aging. Many components come with the un-separated package. It is identified in 2 locations: the Work order and the WIP. Both locations have varied aging control. Therefore the WIP will become over aged earlier than the Work Order. On the other hand, the production staffs need to focus closely on the WIP KPI to keep their performance on track. An item must be moved into a new work order before it is due or quickly returned to the store. These seem to be non-value added activities, but it forces the production team to maintain their inventory performance, and it helps to accelerate the movement of inventory.

Transportation waste: The activity is conducted to analyse this waste in the case study. The company conducted an analysis about how to minimise the travel of the product and the result suggested that setting the layout by product will involve less travel than setting the layout by process. The concerning criteria in this analysis are the total capacity plan to support fluctuating demand; the flow of materials on the

production floor for which transportation waste must be minimized; the company safety regulations, the investment cost, space utilization, and also the relocation plans and schedule and facility support. This analysis cannot be implemented because of the high investment cost at the facility and the lack of a free production time slot. Nevertheless, the situation changed at the end of the product lifecycle when there was a big change in the capacity plan. The company has to review its space utilisation to match new demand. This waste analysis can be used as a reference in the line improvement. The new production floor is arranged by product and the benefits of this change are seen directly by the shop floor management, such as the increased visibility of the material flow and a shortened distance of material movement through the process. This provided a benefit by reducing the head count of production supervisors. However, this waste is related to the facility layout, which is difficult to change rapidly.

Idle/Waiting + Unnecessary Motion waste: This waste involves the waste of human resources. The paper suggests that the increase of resource flexibility will rescue this waste and will make production run smoother. Work improvement such as work sampling and micro motion studies can help to provide useful production data. The capacity can then be improved after reducing idle time. However, during the change stage, they need to handle the resistance to change while maintaining quality. After closing the gaps among teams, there is a win-win solution: the production line can gain more utilisation and operators can improve their skills in wider areas. Production can operate with a more flexible operation, which requires more skill

Defect and Excessive processing waste: These two types of waste are related to the engineering team. Defects impact the weekly process yield. Therefore, if the process can be maintained at an acceptable level, the production will not have any impact on cost, quality or delivery issues. Furthermore, if they face a fluctuating situation such as yield drop, sometimes production needs to load more inputs to meet commitments to customers. The process engineer is the engineer who ensures the process has produced quality products at low cost. Moreover, the non-value added process seems mostly likely to be the cause of excessive processing, which is unnecessary to the product, but it is very hard to define. Because of the characteristics of businesses which are contract manufacturers for a customer, any change requires official customer approval, so a production company is required to prepare supporting evidence to prove that a change in process would not impact the quality of products.

Over Production waste: This waste is not found much in this kind of business; however, it will happen in some cases, for instance, a change from a supplier, or improvements in the yield level.

Discussion of the Value to Sustaining Supply Chain Operations

The combination of high and low volume and unstable demand manufacturing is a challenging characteristic in our case study. Another challenging issue is how to educate people to enhance the performance of the supply chain. From the case study, a lean manufacturing approach is used to transform the EMS to lean EMS and includes

the continuous improvement activity, which is a top-down process; while the Kaizen activity which is applied from the bottom- up and the 7 wastes analysis, which is shown in Figure 1. An additional approach starts with inventory optimization, the operations of the supply chain, and the performance and effectiveness of demand management. The lean manufacturing techniques implementation provides value for a company and can increase efficiency. Incidentally, the problem from a supply perspective is the supplier lead-time variation. For instance, the literature suggests ways in which it is possible to classify inventory and apply specific policies, such as VMI by creating a hub in place, and fixed supply in a class C inventory, which reduced the lead-time and variation of lead-time from suppliers. What-if analysis, Max kits analysis and 12-Week Shortage Analysis are tools that can cope with uncertainty. Yet, the importance of lean manufacturing is to increase business performance and the efficiency of the supply chain.

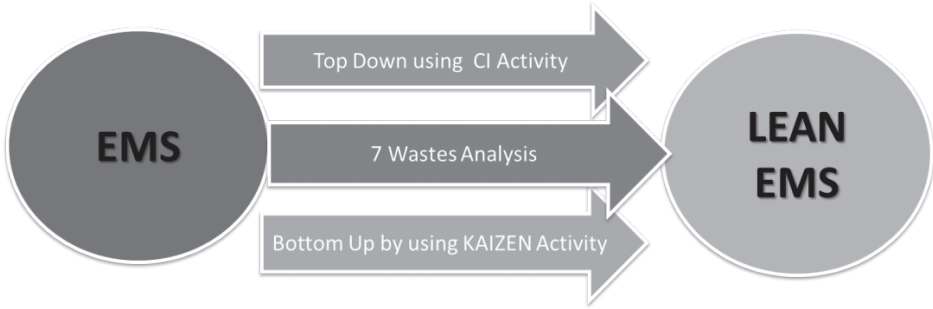

Figure 1:
Transformation of EMS to Lean EMS in the Case Company

The case study confirmed that both Kaizen and continuous improvements activities could sustain the supply chain operations and indeed a good strategy to reduce waste. Management participation is needed to inspire all team members and to engage in continuous improvement. Rewards and incentives should be sufficient to strengthen the system and make it work smoothly. However, our case study also revealed that the company must have organizational culture at the beginning of the Kaizen and continuous improvement activities. Kaizen classifications are divided into 5 types and the KPI require the participation of all employees. This way they can sharpen the focus on Kaizen and continuous improvement activities, and staffs are motivated to participate. Kaizen and continuous improvement activities seem to work well for the employees, especially those of the shop floor level. However, one of big challenges in Kaizen and continuous improvement activities is how to effectively motivate other employee. Price reward as an incentive tool is encouraging other employees who also want to see greater involvement with upper management.

The concept of lean manufacturing serves as the foundation that focuses on eliminating waste and adding more value to products and services. This case study describes the seven wastes and concentrates on waste disposal. Discussions are on the problems of waste of inventory, low inventory movement and inventory aging. Businesses should review production on a regular basis. Difficulties in inventory waste, the amount of data needed to compile and prepare reports are topics for consideration.

There is also discussion on the transportation waste which concerns the distances travelled by materials moving through the production line. Our case study has found that a shop floor layout organized by product type is a better layout in terms of minimizing

transportation compared with organization by process type. However, it is related to the facility layout, which is hard to change quickly. After that, the idle and unnecessary waste is discussed which considers wastes in human resources. Our analysis confirmed that increasing the flexibility of resources can reduce waste and make supply chain operations run much smoother. The importance and the effects of the implementation of lean manufacturing are summarized in Table 2.

Key Focus	Kaizen and CI activities	7-Waste
Importance	• The good atmosphere at the start of the program of Kaizen and CI activities • good preparation • clear KPI setting • Employees positive outlook	• Priority consideration of waste reduction • The first priority always considers inventory waste • Production resource flexibility
Effects or impacts	• The employee reward /incentive • The back-up to employees from top management • The technical support on Kaizen and CI activities • The results of evaluation	• The seven waste reduction in practice • The resistance to change • The amount of information

Table 2: The key focus points in the lean manufacturing

Conclusion

As we explored above, lean manufacturing approach has various impacts on sustaining supply chain operations. The case study has described the findings from in-depth observations and interviews at a case company. Our case study analysis has implications for manufacturers. In general, how the implementation is managed is more important than the techniques and approaches to be implemented. In other words, the major factor in implementation is the directions from top management to the individual operators in the production line, who have the same goal, to enhance the supply chain operations. The technical aspect, if planned, agreed, and planned properly, can be easily deployed. Another implication from our framework is that two lean techniques (continuous improvement and Kaizen activities) really work. The approach described above for sustaining supply chain operations goes a long way toward guiding effective decisions on sustaining supply chain operations.

As with all case studies, the collection and analysis of information creates new research questions and opportunities. The current case study identifies the value of lean manufacturing in supply chain operations. Because supply chain operations workers involved in operations development often work as teams or groups, an interesting extension to the framework developed here would involve dynamics of co-workers and effects. This provokes interesting questions, such as "How do the team dynamics effect supply chain operations?" will help to make a reference for the application of lean manufacturing implementation that should help in current businesses. This paper also provides various opportunities for further research:

- Flexibility in the optimization of resources: a key factor in implementing lean manufacturing is the flexibility of resources; the flexibility to be able to get added value in the operations of supply chain management especially in the electronic industry.

- To broaden the study scope to upstream or downstream operations to make comparisons of the benefits gained in single and multiple operations and also throughout the supply chain. However, the expansion of research may be more complicated because business units that are in competition are not comfortable to share their information, especially with high uncertainty, low volume businesses.

References

Abdulmaleka, F. A. & Rajgopal, J., (2007), "Analyzing the benefits of lean manufacturing and value stream mapping via simulation: A process sector case study", *International Journal of Production Economics*, Vol. 107, No. 1, pp. 223–236.

Aitken, J., Christopher, M., Towill, D. (2002), "Understanding, implementing and exploiting agility and learnness", *International Journal of Logististics: Research and Applications,* Vol. 5, No. 5, pp. 59–74.

Bhasin, S., (2011), "Measuring the leanness of an organisation", *International Journal of Lean Six Sigma,* Vol. 2, No. 1, pp. 55–74.

Buzby, C. M., Gerstenfeld, A., Voss, L. E. & Zeng, A. Z., (2002), "Using lean principles to streamline the quotation process: a case study", *Industrial Management & Data Systems,* Vol. 102, No. 9, pp. 513–520.

Chiarini, A., (2011), "Integrating lean thinking into ISO 9001: a first guideline", I*nternational Journal of Lean Six Sigma*, Vol. 2, No. 2, pp. 96–117.

Christopher, M. (2000), "The agile supply chain: compteting in volatile markets," *Industrial Maketing Management,* Vol. 29, No.1, pp. 37–44.

Cudney, E. & Elrod, C., (2010), "Incorporating lean concepts into supply chain management", *International Journal of Six Sigma and Competitive Advantage,* Vol. 6, No. 1/2, pp. 12–30.

Danese, P., Romano, P., & Bortolotti, T. (2012), "JIT production, JIT supply and performance: investigating the moderating effects", *Industrial Management & Data Systems,* Vol. 112, No. 3, pp. 441–465.

Dennis, P., (2007), *Lean production simplified: a plain language guide to the world's most powerful production system*. 2nd ed. New York: Productivity Press.

Department of Industrial Works, (2012), *2011 year end Thailand Factory registeration information*, Bangkok, Thailand: Department of Industrial Works, Ministry of Industry.

Detty, R. B. & Yingling, J. C., (2000), Quantifying benefits of conversion to lean manufacturing with discrete event simulation: a case study. *International Journal of Production*, p. 429–445.

Flumerfelt, S., Siriban-Manalang, A. B. & F.-J. K., (2012), "Are agile and lean manufacturing systems employing sustainability, complexity and organizational learning?", *The Learning Organization*, Vol. 19, No. 3, pp. 238–247.

Fullerton, R. R. & Wempe, W. F., (2009), "Lean manufacturing, non-financial performance measures, and financial", *International Journal of Operations & Production Management*, Vol. 29, No. 3, pp. 214–240.

Gembutsu, Lean Manufacturing Consultants, 2009. The Benefits of Lean Manufacturing: Single Piece Flow. [Online] Available at: http://www.gembutsu.com/articles/leanmanufacturingprinciples.html [Accessed 21 5 2012].

Gilley, A., 2005. The manager as change leader. Westport, Conn.: Praeger Publishers.

Gill, H., Lopus, M. & Camelon, K., 2008. Overcoming Supply Chain Management Challenges in a Very High Mix, Low Volume and Volatile Demand Manufacturing Environment, Bangkok: Fabrinet.

Hallgren, M. & Olhager, J., (2009), "Lean and agile manufacturing: external and internal drivers and performance outcomes", *International Journal of Operations & Production Management*, 29(10), pp. 976–999.

Hilletofth, P. & Eriksson, D., (2011), "Coordinating new product development with supply chain management", *Industrial Management & Data Systems*, Vol. 111, No. 2, pp. 264–281.

Hutchins, D., 1999. *Just in time.* 2nd ed. Aldershot: Gower.

INVESTOPEDIA, A Frobes Digital Company, online, 2009. Inventory Turnover. [Online] Available at: http://www.investopedia.com/terms/i/inventoryturnover.asp [Accessed 16 5 2012].

Jørgensen, B. & Emmitt, S., (2008), "Lost in transition: the transfer of lean manufacturing to construction. Engineering", *Construction and Architectural Management*, Vol. 15, No. 4, pp. 383–398.

Leong, T.W. and Teh, P.L. (2012), "Critical success factors of six sigma in orginal equipment manufacturer company in Malaysia". *International Journal of Synergy and Research*, Vol. 1, No.1, pp. 7–22.

Liker, J. K. & Hoseus, M., (2010), "Human Resource development in Toyota culture." *International Journal of Human Resources Development and Management,* 10(1), pp. 34–50.

Naylor, J. B., Naim, M. M. & Berry, D., (1999), "Leagility: Integrating the lean and agile manufacturing paradigms", *International Journal of Production Economics*, Vol. 62, pp. 107–118.

Palmer, I., Dunford, R. & Akin., G., (2009), *Managing organizational change: a multiple perspectives approach.* 2nd ed. Boston: McGraw-Hill Irwin.

Rubrich, L., (2004), *How to prevent lean implementation failures: 10 reasons why failures occur*. Fort Wayne, Ind.: WCM Associates.

Santos, J., Wysk, R. & Torres, J. M., (2006), *Improving production with lean thinking*. Hoboken, N.J.: John Wiley.

Schein, E. H. (1990), "Organizational culture", *American Psychologist,* Vol. 45, pp.109–119.

Shetty, D., Ali, A. & Cummings, R., (2010), "Survey-based spreadsheet model on lean implementation", *International Journal of Lean Six Sigma*, Vol.1, No. 4, pp. 310–334.

Slompa, J., Bokhorsta, J. A. C. & Germsa, R., (2009), "A lean production control system for high-variety/low-volume environments: a case study implementation", *Production Planning & Control*, Vol. 20, No. 7, pp. 586–595.

Stalk, G., Evans, P. and Schulman, L.E. (1992), "Competing on capabilities: the new rules of corporate strategy", *Harvard Business Review*, Vol. 70, No. 2, pp. 57–69.

Stank, T.P., Davis, B.R. and Fugate, B.S. (2005), "A strategic framework for supply chain oriented logistics", *Journal of Business Logistics*, Vol. 26, No. 2, pp. 27–45.

Tompkins, B., (2006), Supply Chain Edge:Lean Thinking for the Supply Chain. [Online] Available at: http://www.tompkinsinc.com/publications/competitive_edge/articles/06-04-Lean_Supply_Chain.asp [Accessed 16 5 2012].

Toussaint, J. & Gerard, R., (2010), *On the Mend.* Cambridge, MA: Lean Enterprise Institute, Inc..

Trent, R. J., (2008),. *End-to-end lean management: a guide to complete supply chain improvement*. Ft. Lauderdale, FL: J. Ross Pub.

Tsai, K.H., Tsai, M.L. and Wang, J.C. (2012), "Supplier collaboration and new product performance: a contingency model", *Industrial Management & Data Systems*, Vol. 112, No. 2, pp. 268–289.

Webster, S., (2008). *Principles and tools for supply chain management*. Boston: McGraw-Hill/ Irwin.

Wilson, L., (2010), *How to implement lean manufacturing*. New York: McGraw-Hill.

Womack, J. P., Jones, D. T. & Roos, D., (2007), *The Machine that Changed the World*. London: Simon & Schuster.

Appendix A: Case Company Background

The case study is regarded as an Orginial Equipment Manufacturer (OEM) in Thailand's electronics industry. The technology experience has been transferred to the manufacturing base and has to provide a list of suppliers or vendors that will supply all of the components for the assembly process. The company also provides highly complicated engineering and precision manufacturing for complex optical electronic components, modules and bulk optics. Most of the demand characteristics in the optical electronic industry are complex, high-mix, and low-volume. Many products are also mass volume, such as SMT line produce the PCBA, which supports many internal and external customers. Consequently, the company has strict quality practices and manufacturing process disciplines in every aspect of its operations and also offers customers a cost advantage with a stable value proposition for highly complex manufacturing products. All staff are trained in Six Sigma and Kaizen standards, and focus on continuous improvement in all functional areas. They are also certified in many ISO 9002, ISO 13485, TL 9000 and TS 16949-certified facilities. As an EMS site, the Company has structured itself as "a small factory under the same roof" which offers the ability to establish processes and manufacturing operations uniquely controlled to a particular customer or product, and all production lines are offered complete IP security.

The company has strength in vertical integration manufacturing as there is more than 1,000,000 square-feet of world-class manufacturing capacity, Class-100 clean rooms, onsite testing and reliability labs, and industry leading expertise for precision optical electronic component assembly. There are plants located in Thailand, and China. Nowadays, there are over 4,500 employees all over the world. They are experienced process engineering staff and more than a third of their engineers hold advanced engineering degrees from universities overseas. They also have widely equipped factories to guarantee a swift rise to full production, surpassing yield and reliability requirements through an ongoing process of engineering optimization to maintain flexible capacity to match the level of customer demand. The most required process skill in the company is process transfer expertise. They have considerable technology to transfer the qualified optical electronic manufacturing process from the customer to their sites. With their highly skilled and experienced staff, they have made themselves the leading choice for EMS while seeking to improve operational efficiency and reduce manufacturing costs. The company gained their customer base with a reputation for supreme customer service in the industry and this is the key for their continuing success. At that moment, the supply chain expertise of the company has intense resources to ensure a dynamic response to their customers' market ranging from high-volume, high-velocity material flow using vendor managed inventory to low-volume, high-mix programs supporting turn-key operations.