

Full Length Research Paper

Approaches and practices of lean manufacturing: The case of electrical and electronics companies

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Lean manufacturing is now one of the most powerful manufacturing systems in the world. Numerous plants around the world have attempted to implement or adopt it to enhance their efficiency. However, little studies regarding lean manufacturing have been done in Malaysia especially in the electrical and electronics industry. The purpose of this study is to investigate the approach of adopting lean, the tools and techniques implemented, the changes in the organizations, the problems encountered as well as the lessons learnt. This paper describes the results and findings of four industrial case studies conducted in different electrical and electronics companies in Malaysia. Interviews were conducted with the key personnel to answer some issues which were crucial in this study. Comparisons and discussion were made among the case companies. One of the key findings obtained is that people in the organization should possess the lean mindset and act in the lean way in order to make a lean initiative successful. This is perhaps the first study that investigates the actual implementation of lean manufacturing in the Malaysian electrical and electronics industry. The information presented in this paper can be used or emulated by other companies in the same industry to improve their operational performance.

Key words: Lean manufacturing, implementation, case studies, electrical and electronics, Malaysia.

INTRODUCTION

Developed by the most competitive automotive manufacturer in the world, lean manufacturing has been popularized in many western industrial companies since the early 1990s (Sánchez and Pérez, 2001). It has become a universal production method and numerous plants around the world have embraced it in order to replicate Toyota's outstanding performance. Though lean manufacturing started in the automotive industry, it was reported to be applied in other sectors as well (Liker and Morgan, 2006; Taj, 2008). Today, many organizations are enthusiastic to adopt lean manufacturing in order to improve their performance in this competitive globalized market where uncertainty is prevalent (Wong et al., 2009a). The electrical and electronics industry in

Malaysia has always faced heightened challenges such as rising customers' expectation, fluctuating demand, and intense competition. No doubt, organizations in this industry are always embracing changes and improvements, and thus they need to be more efficient in their key activities or processes to cope with the challenges. It is believed that this sector has started to implement lean manufacturing due to continuous pressures to improve operational performance and to maintain competitive advantage. However, little studies regarding lean manufacturing have been done in Malaysia especially in the electrical and electronics industry. Therefore, it will be advantageous to carry out a study to understand the practices that have been employed by organizations in this country and also to gather their experiences and lessons learnt in implementing lean manufacturing. The paper begins with a literature review on lean manufacturing followed by the methodology employed in eliciting the crucial information from the case companies.

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Subsequently, the results and key findings of the case studies are discussed. Finally, the paper culminates with conclusions.

Literature review

The findings obtained by the International Motor Vehicle Program (IMVP) in Massachusetts Institute of Technology (MIT) show that lean production combines the best features of both mass production and craft production. It possesses the ability to reduce costs per unit and dramatically improve quality while at the same time providing a wider range of products (Womack et al., 1990). It is a manufacturing system that provides the flexibility required to satisfy the rapidly changing demands of customers. Whoever operates by the cost-reduction principle, meets quality cost and delivery requirements, and wants to eliminate all waste from the customer's value stream surely needs to learn about lean to succeed in the market (Tapping et al., 2002).

Lean production is an integrated socio-technical system (Shah and Ward, 2007), which consists of the social aspects (people and society) and technical aspects (machine and technology). It is viewed as a philosophy that requires both technical and cultural aspects (Bhasin and Burcher, 2006). Many of the lean practices are shop floor techniques that help to eliminate waste in the production floor. Implementation of lean manufacturing was generally tool focused. As a result, the effects of lean manufacturing were only confined in a small area and did not achieve its intended impact on the overall system's performance (Hines et al., 2004). Knowing that, lean has now been embraced in a wider scope that includes human aspects and requires changes in management and organizational culture.

Lean manufacturing offers various tools and techniques that help to tackle different types of waste effectively and improve efficiency in different situations. They have gained a great deal of attention among the researchers. The application of lean tools such as Value Stream Mapping (VSM) was studied in a plastic component manufacturer (Lasa et al., 2008), and in a forging company (Sahoo et al., 2008). Benefits of VSM via simulation in the steel industry were investigated by Abdulmaleka and Rajgopal (2007). Lee-Mortimer (2008) explored the adoption of Kanban in an electronic manufacturer while Álvarez et al. (2009) assessed the implementation of VSM and Kanban in an assembly line. Another element of lean manufacturing, cellular layout, was studied in a small-scale industry (Pattanaik and Sharma, 2009). The usage of other tools was also investigated by Sohal and Egglestone (1994), Kasul and Motwani (1997). Generally, the studies showed that the implementation of lean tools effectively helps the manufacturers to eliminate non value adding activities in their key activities.

On the other hand, human aspects such as the

organizational culture and behavior were also widely studied. Emiliani (1998) stated that applying lean correctly could result in the ability of an organization to learn. Human behaviors have long been recognized in order to work efficiently (Emiliani, 1998). Multifunctional teams, decentralized responsibilities, integrated functions and vertical information systems were a few principles for organizational change in lean manufacturing companies (Karlsson and Åhlström, 1996). Boyer (1996) studied the commitment to lean production and also the infrastructure investments (quality leadership, group problem solving, training, and worker empowerment) that contribute to increased productivity. Communication and management support in lean were also examined by Worley and Doolen (2006). Working practices that successfully follow the lean principles were gathered by Olivella et al. (2008). The facets in human aspects such as motivation, empowerment and respect for people are indeed very important (Hines et al., 2004). They are greatly recognized and it is resolute that people and cultural change are the predominant reasons for failures in implementing lean (Bhasin and Burcher, 2006).

In addition, a few researchers gave an insight on how companies carried out their lean journey. In a research on Toyota Production System (TPS), Spear and Bowen (1999) described how this system that combines social and technical aspects has led Toyota to be the best manufacturer of the world. According to Scaffede (2002), a system which is integrated with the management's vision and implemented by the entire production team is the key of how Donnelly Corporation has converted itself into a lean manufacturer. Research on lean manufacturing has been done in various organizations especially in the automotive industry. However, little studies focus on the electrical and electronics industry and there are limited publications on how lean is transferred and applied in Malaysia (Wong et al., 2009b).

METHODOLOGY

In an attempt to understand the actual implementation of lean manufacturing in the Malaysian electrical and electronics industry, case studies were conducted through a structured interview approach. The case study companies were selected from the respondents which had shown interest to participate in this research. It was not an easy task to get them to participate due to confidentiality and time constraint issues. Eventually, four companies agreed to share some information on their lean journey.

The case study was conducted by asking relevant questions through a structured interview approach with the key personnel who are responsible for lean manufacturing implementation. The questions were focused on several issues that are considered to be important when implementing lean manufacturing such as the adoption approach used by the organizations, the application of lean tools and techniques, the effects of lean manufacturing, and the methods to overcome its barriers. Besides interviews, observations on the documents supplied and short visits to the companies were made. The real life cases provided a platform where behaviors and experiences could be shared. Experiences that contributed to lean manufacturing would be highly beneficial to

Table 1. Details of the companies participated in the case study.

| Company | Main products | Year started lean | Headquarters' location | Respondent/ Interviewee |
|---------|--------------------------|-------------------|------------------------|-------------------------|
| A | Electro mechanical tools | 2004 | German | Lean coordinator |
| B | PCB assemblies | 2004 | Singapore | Lean team leader |
| C | Integrated circuits | 2006 | United States | Principal lean engineer |
| D | Relays and keyboards | 2004 | Japan | Production manager |

other organizations.

All the companies that involved in the case study are subsidiary companies that employ more than 1000 employees. Each subsidiary company's headquarters is located at a different part of the world. It is believed that the subsidiary companies always import the practices from their parent organization. The method and approach for implementing lean would differ as the work culture of doing things varies in different countries. Due to confidential issues, each company name was represented by an alphabet. The companies selected for the case studies must have experience in implementing lean manufacturing. In addition, they are world class manufacturers. By doing this, great benefits can be reaped as lessons learnt can be transferred to other companies. The details of the companies are shown in Table 1.

A case study protocol was constructed to assist the data collection. It serves as a guide and an interview instrument that contains all the relevant questions to be asked when exploring the companies' journey on lean manufacturing. The first section of the protocol aimed to seek the general information of the company such as the products manufactured, the year in which lean manufacturing was initiated, etc. The second section of the protocol gave attention to the method for which lean was brought into the company and how it was spread across the organization. Particularly, it investigated the implementation of lean manufacturing in the company. Topics such as roles of management and lean tools applied for improvement were examined. Outcomes and changes after adopting lean manufacturing were also identified. After that, the obstacles of lean manufacturing implementation were investigated. Finally, the lessons learnt obtained during the implementation process were identified.

Case studies

Generally, it was found that each of the companies was in the intermediate stage of lean manufacturing implementation. Many lean tools and techniques have been applied and they were wisely selected based on the problems and expected results. The companies emphasized on their people and provided training to their employees in order to cultivate them to think in a lean way. This was done in order to have a behavioral and cultural change in the companies. Although hard tools and techniques can improve an operation significantly, soft aspects such as people and culture are equally important in lean manufacturing. Since continuous improvement is the central tenet of lean manufacturing, all the companies admitted that there are still many rooms for improvement. The following section will report each of the individual case studies in detail.

Company A

The first case study was done in an original equipment manufacturer (OEM) that produces electro-mechanical tools. The company has started lean manufacturing since 2004 due to a top down directive from the parent company. The parent company was challenged by one of its major customers to reduce cost. Since the

customer is a leader in lean, it was willing to share its knowledge on this subject. The parent company started to embrace lean manufacturing with the help from some consultants and customers. As it obtained significant results, it has incorporated lean as a whole production system with the aim to achieve a cultural change towards continuous improvement. The production system consists of lean principles and methods that serve as guidelines for all activities. With the production system, the new set of practices was spread to the subsidiary companies throughout the world. In order to initiate lean in Malaysia, several personnel were sent to the headquarters for preparation. They went there to learn about lean and make site visits to several plants which have adopted lean manufacturing. After that, experts from the headquarters were sent to Malaysia to assist them to implement lean manufacturing.

At the beginning, trainings and workshops were conducted to educate the employees on lean principles. After the trainings, an area was picked to conduct a pilot run. During the pilot run, drawbacks were discussed and fine tuning was done with the purpose to achieve improvement. As the employees learned, they were also building up their own training materials to train more people in lean manufacturing. These materials are treated as a part of their production system. Using the developed materials, in house trainings were conducted to train a few selected people who were involved in the pilot run for other areas. The initial area to start with lean manufacturing was in the assembly line because it was linked to their key performance index. The approach for implementing changes was done step by step with one thing at a time. It usually starts with the high running products and changes are prioritized based on what is most significant to customers.

Since lean manufacturing was a customer driven initiative, the company was really committed to implement it. Support was given from the top where the general manager participated in the steering committee. The steering committee was responsible for providing resources and guiding the working team to make positive changes. There was also a lean coordinator to organize the lean activities and drive the changes. Structured workshops were the main approach to educate the employees on lean using the modules that have been developed. Operators in production lines were also given training to perform simple improvement at work stations. Points were given to those who gave suggestions and they could exchange the points with small gifts as rewards. The company not only implemented lean, it also developed its own local suppliers to become lean. Experts from the company were sent to the key suppliers and trainings were given to them free of charge. However, the company demanded profit sharing when the cost was reduced. Company A also welcomed its suppliers to visit its factory so they could observe and discuss how lean manufacturing works.

The company has implemented many lean tools and techniques in these few years. In the manufacturing floor, work standardization became the foundation for all activities. The layout is now transformed into U-shape lines which emphasize on flow orientation so that only minimum movement is required to move work pieces from one station to another. With a balanced takt time, chaku chaku is able to be performed in this layout. This is done in a single piece flow line where the operators proceed from machine to machine, taking a component from one machine and load it into the next. In

other words, the operators are required to work in multiple stations in one line, thus less manpower is needed. Other than that, materials were delivered straight to the point of use in small lots through kanban cards. Milk run system with powered trucks was used to deliver materials from the store or supermarket frequently. Inventory storage time was reduced from weeks to days with kanban system and only minimum stocks were kept. Production became more transparent as kanban system and leveling board were implemented. Productivity charts, maintenance records, quality charts etc. were posted on walls to allow the employees to visually understand the current state by just a glance. In terms of quality, a few tools such as 5 whys, jidoka, and poka-yoke were used to reduce defects with the purpose to produce good quality products for customers. Operators were empowered to stop the line with andon lights when there were quality issues. Methods such as Failure Modes and Effects Analysis (FMEA) and Design for Manufacturing (DFM) were also employed in product design. Audits were performed from time to time to gauge the effectiveness of implementing the lean tools and techniques. It was noticed that the company has an improvement of approximately 5% in terms of quality and an increment of 10% in productivity, as compared to the previous year.

Lean tools such as 5S, quick changeover, poka-yoke etc. were used to support the company's production system principles. Value stream mapping is the first step needed to find out where improvement can be done or needs to be done. The team usually starts with one product line or lines within the same product family. A future state is drawn and the areas that need to be improved are identified. After that, the identified areas will be improved with kaizen activities. Appropriate personnel who are trained will be responsible to carry out the kaizen using the appropriate lean tools. There is no specific way to improve a value stream. It depends on the future state required by the team. Along the implementation, more problems may arise or occur. As for that, another technique or tool will have to be applied in order to solve the problems. Each of the lean tools has different roles and each of them needs to synchronize with each other, just like gears that go hand in hand. The lean committee members will review the kaizen process from time to time to look at the problems and obstacles faced. If they are unable to meet the target, discussion will be held and problem solving methods will be used to find out the cause. If they are able to meet the future state, the project is called successful. Nevertheless, the team will continue to attempt for achieving a higher stage of improvement. This is because lean manufacturing is a never ending journey to perfection.

There were obstacles during the lean implementation process. People's mindsets were the major obstacle as they were inclined to resist changes. They appeared to backslide to the old working methods. For that reason, simulation games were introduced to the employees during the training workshops in order to promote a better understanding on lean manufacturing. When the pilot run is successful, employees can learn the difference between lean and non lean systems. As they notice the benefits and are convinced that lean manufacturing can help them, they will start to develop enthusiasm to achieve it. In order to move forward, commitment from top level managers is crucial. They have to drive the initiative and conduct trainings so that the thinking of the employees could be changed.

Lean manufacturing requires huge investments in time and discipline. It takes tremendous effort to implement various tools. For a starter, a good mentor that could guide and coach the lean team is desirable as he could share his experience and understanding of lean. It is advisable to start with a pilot run on a product line or similar product family to observe the drawback when implementing lean. Team members and managers should go to the production floor to observe the real situation and address the problems through discussion. Standardized work is a must, followed by review to assess the progress and effort to continuously improve the whole

value stream. Moreover, there must be a structured way to systematically implement kaizen projects in order to sustain a lean initiative.

Company B

Company B manufactures printed circuit board (PCB) assemblies. It started to implement lean since 2004 when it received a direct order from the headquarters. A group of consultants was hired directly from the headquarters to train the employees on lean. The company is committed to launch lean due to the market call. Part of the reason is that lean manufacturing has been a hot topic since 2000. The company's aim is to produce optimum outputs with minimum resources to improve profits by optimizing humans, machines, and materials. In addition, Company B also desires to have a cultural change that is able to contribute to continuous improvement with lean manufacturing implementation. The company's approach is to educate the employees on the 7 major waste reductions following the 3 GEN: Genba, Genbutsu, and Genjitsu.

Lean was adopted in areas such as operation, supply chain and office management. The main attention was given to the manufacturing operation which is on electronics assembly processes to achieve high flexibility with optimum outputs. The prerequisite to initiate any program always begins with training to educate the employees. Initially, a few key people were trained by the consultants on the lean subject. The trained personnel then developed their own in-house training program for other personnel. The training started from the director level and continued layer by layer till the technician level. The company adopted a strong approach that is to push its employees to believe in lean and make improvement. The General Managers and Operation Directors play an active role in lean as they act as the kaizen leaders. It is believed that when top hierarchy managers lead a project, their subordinates will have to follow the orders and instructions given by them.

Many lean tools and techniques have been put into practice such as load leveling, standardized work, supermarket, poka-yoke, andon, quick changeover etc. Load leveling was applied to cope with the fluctuating demands as it is a norm that customers' demands are always changing. Manufacturing lines were arranged in a modular form to increase flexibility. In addition, setup time was reduced by quick changeover. The assembly operation applied the single piece flow concept to decrease the inventory level and maintain the quality of products. Basically, industrial engineering tools were widely used in the operation and the focus was to find the waste and eliminate it. A significant change that occurred was the production scheduling is now based on a schedule board at the production floor. The supervisors just have to look at the production board to know which product and quantity to be produced. The planner can only change the schedule for the products that have not been kitted to avoid waste. The processes have become more transparent with visual management. Currently, only a small portion of the company's suppliers have adopted vendor managed inventory methods. In terms of the office, the working places of the engineers were non permanent as they shifted from one project to another. Partitions in the office were also demolished in order to create a new working environment which was to break down the walls of the functional departments.

A few techniques that were scarcely seen in other organizations were identified in this company, namely Hanedashi, 7 ways, and Fish market. For instance, Hanedashi is an auto-eject device that unloads the part from the machine once the cycle is completed. 7 ways is a tool used for solving problems where concepts are brainstormed and listed down (7 ways indicate there are 7 options). Each solution or option will then be discussed and the best option to improve the processes or operations will be chosen for

implementation. Fish market is a place to display 'problematic issues' that need to be solved quickly. They are displayed for anyone who is interested to visit the area. A clean and empty fish market is desired because if the items are put in the fish market for more than a day, it implies that the team is not responsive.

Lean projects were usually done in a group of employees which consists of 5 or 6 people formed by cross functional members. The team members are always changing depending on their project. A guideline that is normally used is to follow the 3 GEN rules, which are to walk the lines, identify the wastes, provide the solutions and review them. VSM was first used to spot the waste and identify kaizen points. The team then discussed which kaizen points should be improved and proposed suggestions utilizing the 7 ways method. Following this, the team members were given tasks with a specific duration according to their area of expertise. The tasks were reviewed to ensure that improvements were done accordingly. Newsletters were used as a communication tool to keep employees informed on the improvements made. The company stated that it was difficult to quantify the reduction of resources because saved resources would be used by other projects. Nonetheless, a lean maturity tracker was used to evaluate the company's progress in lean. A few criteria assessed were like leadership, implementation of visual management, defects, etc. The results were favorable as the tools implemented showed progress and improvement.

Due to the nature of its business, the company can only apply lean knowledge to those customers and suppliers that believe in lean manufacturing. The barrier when implementing it was people. There was resistance from the employees because they believed lean would increase their work load rather than helping them to work better. However, the resistance dropped as they learned that lean projects could help them to perform their job in a better way. The approach taken by the company to help the employees learn was to enroll them in kaizen activities.

The journey to lean in the company marks a positive sign as it is able to increase flexibility and use lesser resources to produce products. Scheduling became more transparent as the production schedule is now put at the production floor. In addition, Company B became better in coping with fluctuating demands as modular lines allowed greater flexibility. The employees were trained to observe directly at the real situation, and to provide suggestions or solutions to the problem with the rules and techniques taught. It was acknowledged that lean is learned by doing; people have to believe that it can work. A group of people that believes in lean manufacturing can become its driving force. Self sustaining methods need to be developed in order to make it keeps going. Lean is a journey, anything that has been saved will be used up and the cycle keeps repeating with no ending.

Company C

The third case study was done in an American subsidiary company located in the northern part of Malaysia. As an electronic chip manufacturer, it has embarked on lean manufacturing for around 4 years in order to increase effectiveness which is to get more with less. The effort to embrace lean manufacturing was a top down initiative that came from the General Manager of a subdivision of the company. To start the journey, the company hired consultants to educate its employees about lean. A lean house model that focused on behavioral change to improve products, people, and tools efficiency was adopted. For the company, lean is a way to get better results and efficiency.

In order to increase efficiency across the factory, everyone in the company is needed to participate in the lean journey. Based on this, educating the employees on lean through trainings and workshops is the first step. With the aim centered on behavioral change, the company is focusing on the lean fundamentals, principles and rules. The trainings were given according to the company's hierarchy. The

top managers went through the training first before the employees so that they could support and encourage lean transformation. In depth courses regarding lean have been given to almost two hundred employees till now. The trainings were structured into three categories which are education, application and communication where each part contributes significantly to the success of lean. It is important to emphasize on education first so that the people can understand lean with the same basic skills and language when communicating. With a common ground, sense of unity, and clarity of purpose, communication is easier and more effective (Flinchbaugh and Carlino, 2006). Using the same language enables people to see waste and discuss opportunity with their eyes more open. A total understanding and acknowledgement of lean will make them believe that lean can really work for them. According to Flinchbaugh and Carlino (2008), beliefs will drive behaviors, behaviors will drive actions, and actions will generate results. Therefore, believing and understanding why and how the concept is implemented is certainly essential.

The company wished to craft its own and unique journey, not by copying what other companies are doing in lean. Each division does not have to follow a specific way when implementing lean improvement. The division heads determine what is needed to be improved in their own division according to their own needs. Thus, some departments may have to focus on SMED and TPM, while other departments emphasize on labor and cost reduction. The major focus is on the utilization of machines because this is where the huge investment is. Tools such as quick changeover and preventive maintenance suited well with the company. Other than that, mapping techniques and lean problem solving methods were also learned and adopted. These tools and techniques engage the workers to go to observe the condition directly, understand the current reality, and set a target where they want to be. The focus is not only on the results anymore, but is on how to create a new and better situation. Open discussion is held to talk about the possibilities that can be achieved in the future. This is because discussion activities indirectly create a learning environment for the employees. 5S, work standardization and visual management were also being adopted to support lean.

Lean tools are meant for improvement and to achieve the ideal state. The reason for applying lean tools must be known before they are implemented. They must be studied well before implementation as different factories have different business natures, current states and resources. The company did not focus on the usage of some lean tools such as kanban, one piece flow, heijunka etc. The reason given was because it has just started embarking on lean and its way of approaching lean is mainly focused on people and cultural transformation rather than copying what tools other organizations have implemented. The company realized that importing tools into a legacy system will almost always fail to drive any significant change. The failure is due to companies do not understand the needs for adopting the tools, and the tools do not fit within the organization's broader set of principles, practices and methods (Flinchbaugh and Carlino, 2006).

A distinctive instrument for learning purposes was created. A learning card was placed beside the machine for the technician to write down the problem faced and the solving method. As there are four shifts in one day, the employees in a particular shift may not know what is happening before and after their shift. Because of this, they may solve the same problem which has already been solved by their colleagues in a different shift. The learning cards record down the activities done to the machines and knowledge is transferred when other people read them. With this, they can have a better solution each time when a problem arises as the information is flowing from shift to shift.

There were some significant outcomes after embracing lean manufacturing for around 4 years. Although the effectiveness of lean has yet to be measured quantitatively, some positive changes in terms of human behaviors were able to be observed. With the

approach to define a problem and formulate a hypothesis as a solution, the employees are spending time to explore the ideal state where they might achieve rather than providing predetermined answers which might give the wrong solution. This provides more opportunities to achieve efficiency. As time goes by, the employees have also become more aggressive to accomplish their tasks rather than waiting for their managers to set goals for them. Moreover, it is also noticeable that the managers are now spending more time on the production floor rather than having meetings in the room to understand and solve problems. Through direct observation, they can know what is really happening on the production floor.

Obstacles are inevitable as the company also faces resistance from the employees. Some employees treated lean as another program that the company is focusing on. It is hard for the company to convince them that lean is a cultural change, not just a program. However, it is believed that as more and more employees understand the journey of lean, they will notice the change in the environment and believe that lean is the way to move forward. The company also appears to have some complications in dealing with the reward and recognition for individual contribution which relates to lean manufacturing. It is realized that these challenges might take a couple of years to be solved.

Though lean covers wide areas, the company's approach is to start things which are in control and do things step by step. It is also understandable that to implement lean manufacturing, support and commitment from top management is crucial. Managers not only have to believe in lean manufacturing but they also need to coach and guide in order to drive and lead the change in the company. A more formalized structure that focuses on lean is needed. In order to make lean sustainable, it is important for everyone to constantly talk about the good and bad behaviors, and spend more time to have direct observations, understand the problem, find the root cause and then improve it. It is suggested that companies which want to start their lean journey should understand the 10 factors given by Flinchbaugh (2004) before embarking on it. The 10 factors are:

- (1) Rome was not built in a day.
- (2) This is not a part-time job.
- (3) Lean is more than just tools.
- (4) Lean is a journey that never ends.
- (5) Be prepared for resistance.
- (6) You need leaders to take on this challenge, not managers.
- (7) Be prepared for the investment - both people and time.
- (8) Lean is not just about the shop floor.
- (9) There is no recipe, but there is a roadmap.
- (10) Do not just copy the answers.

Company D

The last case study was done in a company that manufactures keyboards and relays. Lean manufacturing was called 'TPS' (Toyota Production System or Thinking Production System) in Company D. TPS was introduced in this company when it was struggling in the market as its sales slumped. Since it is also a subsidiary company, its headquarters in Japan provided TPS as the path for survival. Goals and directions were set in this new initiative. A slogan 'Good Thinking, Good Work, Good Quality' was created in line with TPS. The awareness of waste was given great emphasis in order to eliminate the major waste across the organization. The company also asked help from a sensei in Japan. The 1st day visit of the sensei gave a good impact to the company as he showed the employees what waste was and where the hidden waste was located. The management team noted down all the findings and started to find ways to improve the situation gradually. Since then, the results were starting to show positive trends.

To start lean in the company, the senior management including

the Managing Director took the lead by going to Japan to understand the basic concept of TPS and how it was applied and implemented in the factory. Upon returning to Malaysia, a group was formed to start the activities of TPS. Waste reduction was focused on the 4M: man, machine, material, and method. Top management and senior management also play an important role to support TPS activities. They take part in study groups that routinely audit each department to observe the current situation and give suggestions to areas that can be improved. This shows the commitment of the management in implementing TPS activities for the sake of survival in this competitive market.

Trainings were carried out from top to down and they could be separated into formal and informal. The formal trainings began with the introduction of TPS and its related concepts such as kanban and heijunka. The trainings were followed by 4 modules of quality control circle (QCC) where the aim was to create more sensible workers with good thinking in order to produce good work that contributes to good quality products. Besides this, the trainings also helped to motivate the employees to give suggestions for improvement. Morning meetings or weekly meetings were regarded as informal trainings because the managers would coach and guide the workers to solve problems using the TPS principles.

Lean tools and techniques were applied to attain the target set by the headquarters. Improvements were made gradually as a lot of background studies were needed before things could be implemented and they were time consuming. Inventory and work in process (WIP) were reduced gradually by around 10 to 15% in each quarter of a year using kanban and heijunka. Small storage with calculated size located beside the machines helped to prevent overproduction. Water spider, a person assigned to support an operation so that other workers may focus exclusively on value added work was applied to collect the goods produced by the machines according to the First-In-First-Out rule. Raw materials replenishment size was reduced from pallets to bags. Machines availability was increased using preventive maintenance and short control methods. In terms of ergonomics, the working desks were designed to suit the heights of the employees using screws to lift or lower the desks. All workers were required to stand except for certain specific processes. Rearranging the layout of the production floor was not practical because it involved high cost. This is because when the machines are relocated, the utilities need to be repositioned as well. Workers were encouraged to give suggestions to improve their work. Monetary rewards were given for filling up the suggestion forms; RM1 for each suggestion and RM10 for a suggestion that was implemented. RM200 were given to the champion who contributed the most to the department. Employees were also taught to solve problems using systematic methodologies. Two major problem solving methods applied were plan-do-check-act (PDCA) and define-measure-analyze-improve-control (DMAIC). In addition, visual controls were used as a communication tool. Information regarding productivity, sales and quality can be simply obtained through visual charts. Pictures of defects were also given to the operators to differentiate which parts should be rejected.

Lean tools do help in the production. It is said that the heart of TPS lies in heijunka. To implement tools such as kanban and heijunka, a proper understanding of the current process is needed. For example, heijunka is linked with various factors, such as production scheduling, material handling, equipment availability, etc. It requires a lot of studies about the background process that is going to be affected. Basically, the tools or techniques to be implemented should always be simple and practical. This will be seen as a clever step when they meet the objective. The unique way in this company to sustain lean is the study group that consists of directors and managers. They routinely go round the factory to give suggestions for improvement following the 3 GEN rules. The awareness of waste may be different for each person; the person in charge of an area may be blinded by the hidden waste because he is accustomed to the environment. The study group that consists of

all department managers can spot irregularities more easily and give constructive ideas to improve the situation. On top of that, the suggestions also require prompt corrective actions as they will be reviewed in 2 weeks time.

After years of doing lean activities, the managers started to grasp the concept of waste. They began to understand how their first mentor from Japan saw the wastes that were hidden in their production. With the knowledge in identifying wastes and non value adding activities, steps were taken to reduce or eliminate them. Other positive changes were able to be observed as well. Heijunka and kanban helped to lower the WIP level on the production floor. The production area was like a storage room before the implementation but now it is more organized and conducive. Cleaners are no longer needed in the production area as the workers now are used to clean up their working area and they know that it is part of their responsibility. The workers are also seemed to be more aggressive in solving problems and more motivated to work. Overall, the implementation of lean manufacturing has helped the company to achieve the target determined by its headquarters (that is, 40% reduction of waste such as spoilage and WIP in a year).

Resistance especially from senior workers is always the common problem when implementing lean manufacturing. Senior workers have the thinking that the management is trying to squeeze them harder, thus they constantly reject new ideas to do their jobs. TPS is a production system that requires the change of working method. The workers must believe that the new method can help them rather than burden them. In view of that, specialists from Japan were brought in to work together with the workers. The rationale for doing this is to let the workers see and feel for themselves the way and attitude of how the Japanese are working. It challenges them and serves as a good motivation when the Japanese can accomplish projects and solve problems which they haven't done before in Japan. Budget constraint is also one of the obstacles of TPS activities in the company. A SMED program was halted due to financial reasons. Although it appears to save time for changeover, the company justified that faster changeover may not produce high quality products. This is because the main reason for producing non quality products is due to improper maintenance of dies.

Implementing and sustaining lean need a lot of efforts. The first prerequisite is to have a good thinking in believing that TPS can help the operations. A good thinking will result in good work which is aligned with the company's slogan. The efforts should always come from the top and deliver down to the managers and employees. Commitment and strong willingness from the board of directors to take part directly in the activities such as giving suggestions and support on the shop floor are crucial. They also need to motivate and challenge the employees to change for the better. A common metric should be created for all departments to measure the progress of lean manufacturing implementation. A master schedule for the implementation followed by a breakdown schedule for each department is the subsequent step. Other than that, a formal reporting format is also needed to enable data synchronization. Kaizen activities should always follow the PDCA cycle. Persistence is needed to keep the improvement cycle going on, as lean is a never ending cycle.

RESULTS AND DISCUSSION

Lean manufacturing has been implemented between 4 and 6 years in the case companies. Generally, they started lean manufacturing as it was a top down directive mainly to reduce cost in order to stay competitive and survive in the market. Since there is no standard way to implementing lean manufacturing in Malaysia, different companies adopted it in distinctive ways. Lean has been

integrated as a production system in Company A while Company C adopted a model as a guideline to embrace it. Other companies have their own principles and elements that characterized lean manufacturing. However, there are many similar practices adopted that can be identified among the companies such as visual management, standardization, and 3 GEN. Their goal in adopting lean manufacturing is unison which is to have a cultural change on how the people work to achieve continuous improvement.

The top managers of the companies are committed and serious in adopting lean manufacturing. They place particular emphasis on making lean as a company-wide culture and not taking it just as a program of the season. They also play an active role in lean activities. For example, Company D's managers were involved in the study group to give their suggestions on the production floor biweekly. Company A's directors were engaged in the steering committee to make positive changes happen. Managers in Company B became the role models or leaders to drive lean initiatives. They are aware that without the full commitment from top management, any initiative would certainly fail. Significant advantages can be obtained when the leaders lead by example. As they put lean concepts into practical behaviors, workers can observe and have a better understanding and even emulate them.

Trainings and workshops are necessary in order to spread lean across the organizations. Employees need to understand the fundamentals and concepts of lean manufacturing. Trainings were given according to their needs and responsibilities in order to train them to be more aware of wastes. It is learnt that in order to be successful in lean, the key factors are the employees. There is a company which employed a persuasive approach while there is also another company that used forceful approaches to get everybody in the organization to participate in lean projects.

Lean manufacturing offers a lot of tools such as kanban, heijunka, jidoka etc, to improve manufacturing operations and each tool is complementary to each other. Table 2 illustrates the lean tools adopted by the companies. It is seen that the companies which have implemented lean manufacturing for about 6 years had adopted many tools and techniques to improve their production. Improvements were done in specific areas according to their needs with the help of lean tools and techniques such as value stream mapping, heijunka, kanban, SMED, one piece flow, etc. For example, value stream mapping was employed to identify the opportunities for improvement while 5 whys was utilized to find out the root cause of the problem. Each tool utilized has to be synchronized with each other to reduce the identified waste. In addition, all the companies carried out lean activities in teams. Working groups and teams were formed with cross functional members.

Table 3 shows the lean tools that are grouped

Table 2. Lean tools implemented among the companies.

| Tools and techniques | Company | | | |
|---------------------------------------|---------|---|---|---|
| | A | B | C | D |
| Number of years in lean manufacturing | 6 | 6 | 4 | 6 |
| 5S | * | * | * | * |
| 5 Whys | * | * | * | * |
| A3 | | | * | |
| Andon | * | * | | * |
| Cellular Layout | * | * | | * |
| First-In-First-Out (FIFO) | * | * | * | * |
| Genchi Genbutsu | * | * | * | * |
| Heijunka (Load Leveling) | * | * | | * |
| Jidoka | * | * | | |
| Just in time | * | * | | |
| Kaizen | * | * | * | * |
| Kanban | * | * | | * |
| Milk run | * | * | | * |
| One piece flow | * | * | | * |
| Plan-Do-Check-Act (PDCA) | * | * | | * |
| Poka-yoke (Mistake Proofing) | * | * | | * |
| Single Minute Exchange of Dies (SMED) | * | * | * | * |
| Six sigma | | * | | * |
| Standardized work | * | * | * | * |
| Supermarket | * | * | | * |
| Total Preventive Maintenance (TPM) | * | * | * | * |
| Value Stream Mapping (VSM) | * | * | * | |
| Vendor Managed Inventory (VMI) | * | * | | * |
| Water spider | | * | | * |

* Tools implemented

according to focus areas. It illustrates some of the tools applied by the companies for improvement in specific areas. As shown, there is no single specific tool to be used in each area. The tools are utilized depending on what is needed in the situation as well as the expectation to achieve the overall strategy. They may serve as a solution for today but they do not necessarily solve the problems for tomorrow. Therefore, the purpose of the tools must be well understood before they are used to avoid misapplication (Herron and Braident, 2007). Misapplication of lean tools may cause adverse effects such as wastage of resources and reduced employee confidence (Pavnaskar et al., 2003). Implementing the tools does not make a company lean but they are the enablers that contribute to becoming lean. They should be implemented hand in hand to achieve the company's targets.

The approach used by all the companies when applying lean tools such as kanban, one piece flow, value stream mapping etc, is always one thing at a time, or piece by piece. For example, one particular line or product family which has high orders and high repeating

cycles was chosen as the initial improvement target. According to the Pareto principle, roughly 80% of the effects come from 20% of the causes. Therefore, the high running product with a stable volume was chosen to be the pilot run because it would generate a huge impact on the company. With a pilot run as a learning platform, people have to use the new working method and see how it works. It may change the layout of the normal production, how the materials flow, and how the people work. A pilot run is also for employees to experiment, learn, and practice lean thinking, tools and techniques. It is a platform for employees to develop their skills in lean. With this, they will start to see what improvements are needed for kaizen activities. It is important to pick an area to begin with in order to learn the pros and cons of the system. Evaluating, reviewing and learning from the mistakes made during the pilot run will surely give a lot of benefits.

Since all the companies are world class manufacturers, they share a lot of common practices. They are well organized, clean, tidy and neat. It occurs that 5S is the most common tool to start with when embracing lean. It is

Table 3. Lean tools grouped based on focus areas.

| Focus areas | Company | | | |
|--|---|--|--|---|
| | A | B | C | D |
| Line design (Safety and ergonomics, processes, layout) | Standardized work, line balancing, takt time, MTM, eliminate waste, one piece flow, VSM | Waste walk, modular form line, one piece flow, material presentation, VSM, standardized work | Mapping techniques, standardized work | Standardized work, adjustable desk, study group |
| Production scheduling | Load leveling, small lot, follow the production rhythm | Pack plan scheduling | | Heijunka, kanban |
| Inventory reduction | Kanban, supermarket, reduce throughput time | Standard WIP, supermarket, single piece flow, visual control | | Kanban, supermarket |
| Material handling | Straight to the point of use with minimum quantity, milk run | Water spider, supermarket, milk run | | Water spider |
| Equipment utilization | TPM, OEE, SMED | Quick change over | Quick change over | TPM, short control method |
| Quality | Minimum buffer, andon to stop the line, poka-yoke, jidoka | 6 sigma, poka-yoke, zero defect line, andon, hanedashi, fish market | | QC projects, poka-yoke, andon, 6 sigma |
| Suppliers and customers | Partnership with suppliers, develop suppliers in lean, VMI | VMI, replenishment model | | VMI |
| Product design | FMEA, DFM, Poka-yoke | | | |
| People (management and employees) | Training and workshop, steering committee, suggestion scheme | Training, competition and campaign | Training on changing behavior and thinking | Training, suggestion scheme, reward |
| Problem solving | PDCA, Genba, visual factory, FMEA, 5 whys | PDCA, Genba, 7 ways, visual control, 5 whys | A3, Genba, visual management, 5 whys | DMAIC, PDCA, Genba, visual management, 5 whys |

understood that 5S creates a better surrounding by having a good housekeeping. The visual change can be seen by all people and they will feel better when working in a tidier, cleaner and safer environment. Other than that, discipline is required in sustaining 5S. Employees need to be trained to keep their working place clean and in order, where all things are in place. The situation is less chaotic and more stable when everything is in place. As everything is organized, it is also easier to spot 'variations'. Variations are seen as errors that need to be eliminated. As the irregularities of processes surfaced, prompt actions can be taken to solve the problems. Stability is the prerequisite for further improvement. Through 5S and visual management, a stable condition

that is visually controlled is created.

Another important phenomenon observed in all the companies is visual control. For instance, Company A and Company D displayed their quality and productivity charts as well as their maintenance records. The charts illustrate the current trends and performance and serve as an indicator of the current situation. The created visual environment helped employees to obtain information with just a glance. Load leveling boards were also installed in Company A and Company B. The boards visually inform employees on which and when a product is going to be manufactured in order to avoid overproduction. Visual control can act as a communication tool that helps team members to observe irregular conditions. Visual cues can

greatly enhance productivity (Goodson, 2002) as they clearly guide employees to appropriate locations and tasks.

In addition, another important aspect of implementing lean manufacturing is to practice "*Genchi Genbutsu*" which is to go to the place and see for yourself. It is a totally different experience to drawing a conclusion by just looking at reports and seeing the data and numbers in a meeting room, and by going to an area to see what the numbers mean (Sayer and Williams, 2007). Company A's project team has to walk to the production floor to grasp what is really happening rather than having daily meetings in a room. It is seen that the managers in Company C are at the production line more often after they have embarked on the lean journey. Company B and D have also made it as a principle for problem solving. The way of doing things by direct observation at the real place enables firsthand knowledge to be obtained. It prevents solutions to be given based on past experiences without clearly understanding the real situation.

Though all the companies have embraced lean manufacturing for years, they admitted that they are still far from being lean at the current moment. However, they are certain they are progressing well in their journey to lean. Positive changes have been noticed such as: processes are more transparent because everyone knows what should be done, companies are more flexible to change production, teams are more aggressive to achieve things rather than waiting for managers to set goals for them, and the working environment is better as the workers are more empowered.

From the case studies, the main obstacle identified for implementing lean manufacturing is due to the human factor. Employees tend to resist changes or backslide to the old ways of doing things. The major challenge for the organizations is to 'buy in' their people. Employees need to know why the changes are required. They will only be convinced when they understand the benefits that lean can bring. As they notice the benefits and are convinced that lean manufacturing can help them, they will start to develop enthusiasm to achieve it.

In essence, electrical and electronics companies in Malaysia are mostly overseas subsidiaries of multinational corporations in other countries (Wong, 2008) which have implemented lean manufacturing. Therefore, it is usual for these companies to follow the standard and initiative set by their parent organizations. Due to this, the implementation of lean manufacturing would have to undergo a transformation process before its practices can be intertwined and integrated seamlessly into the working context of Malaysia which is a multi racial country. For example, training contents and syllabi were fine-tuned by the case companies to suit the local culture. This transformation process must be carefully managed so that lean initiatives can be accepted by all layers of employees in the organizations. As can be seen, electrical and electronics companies are suitable to implement lean manufacturing mainly because of their standard cycle

time and products that are high in volume and low in variety. This allows many lean tools and techniques to be adopted. Nevertheless, in a volatile and dynamic industry such as the electrical and electronics sector, products may become obsolete in just a short duration. Therefore, a thorough understanding on lean manufacturing is needed so that the right tools and actions can be taken promptly and quickly in order to compete in this industry.

Conclusions

The case studies have highlighted some problems, with some of them solved while some remain unsolved. Each of the organizations has developed its own unique technique and methodology to fit with its current production system. They have also integrated other approaches such as six sigma and QCC to support their lean initiatives. To be lean is to be a dynamic organization that could continually adapt and innovate. It is shown that the most vital part when implementing lean manufacturing lies on the people. Everyone in the organization needs the right tools and support to make positive changes happen. They have to possess the thinking that is able to identify and eliminate waste because lean manufacturing requires systematic problem solving methods. A mindset that can sense and identify waste is useless if no action is taken to eliminate it. Therefore, it is extremely crucial to put the mindset into action. All the companies also admitted that they are still far from being lean and there are much more to be learnt. Thus, it can be concluded that continuous learning and improvement is crucial to achieve a 'lean' state. In essence, companies which want to implement lean manufacturing should continuously train their people to 'think lean' and 'act lean', and support them by giving them the right tools.

This paper has discussed the results and key findings of the case studies. It is found that the main aim of implementing lean is to adjust people and systems in order to deliver the best value to the customer through waste elimination. Though different approaches have been utilized by the companies, it is apparent that lean manufacturing has made a difference in how they perform their work. In conclusion, it is hoped that the information accrued from this article will benefit those who wish to start their lean journey.

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