Lean Manufacturing Implementation in a Plastic Molding Industry

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Abstract

Lean manufacturing is a set of tools and methodologies that aims for the continuous elimination of wastes throughout the production cycle. This research addresses the implementation of lean principles and tools in a small and medium scale industry focusing on the Plastic Injection molding operation. The main target is to plan and test several strategies to eliminate waste on the shop floor. A systematic approach was used for the implementation of lean principles. This paper also describes the application of value stream analysis. The present and future states of value stream maps were constructed to improve the relevant production process by looking for opportunities to eliminate wastes and its sources and finally to improve the overall process flow. The implementation of VSM, 5S, SMED, Heijunka, Small lot size, Kanban, milkrun, layout and process improvement have shown very encouraging results. Productivity has increased to 94.1%, Delivery attainment increased to 100%, Changeover time was reduced to 38.5 minutes and reduction in total inventory to 2.86 days. The implementation of lean manufacturing has proven to be effective and suitable for enabling a continuous improvement process.

Keywords*: Lean implementation, plastic moulding industry, value stream map*

1 Introduction

The Toyota Production System (TPS) or Lean Manufacturing System focused on pinpointing the major sources of waste and then using tools such as JIT, production smoothing, setup reduction, kanban and others to eliminate waste (Abdulmalek and Rajgopal, 2007). It has been proven to be effective in reducing cost, improving quality, increasing productivity, achieving 100% product delivery and managing sudden increase in customer demand. In recent years, lean manufacturing has been widely adopted by manufacturing firms and other sectors as a continuous process improvement projects. The foundation for the system is human-based, where people are involved with continuous process improvements, leadership and empowerment through education and training. However, those who tried using the tools of lean manufacturing without understanding them, eventually failed. But there are number of places this system is working well (Womack and Jones, 1996). This study addresses the implementation of relevant lean principles and tools in a Small and Medium Scale Enterprise (SME) involved with Plastic Injection Molding operation. The main target is to evolve and test several strategies to eliminate waste on the shop floor. A systematic approach was used for the implementation of lean principles. The present and future states of value stream maps (VSM) were constructed to improve the relevant production process by looking for opportunities to eliminate wastes and its sources. Based on the information gathered, the company will utilize the results as a plan to map the future state and implement lean manufacturing tools.

2 Literature review

Lean manufacturing derives its name from the manufacturing systems and processes of the Toyota production system. These systems are highly flexible, responsive to customer requirements and effective in producing goods at low cost with shorter cycle times. Good understanding of lean production definition and its concept are crucial for the researchers. It will ease the process of defining the overall research goals and methodologies (Pettersen, 2009). Vinodh et al. (2010) defined lean as a manufacturing paradigm which aims at continuous reduction of waste to maximize flow. Singh et al. (2010) described lean as a manufacturing concept to reduce waste. Eswaramoorthi et al. (2010) defined it as a multi-dimensional management practice. Alvarez et al. (2009) described it as a strategy, Pattanaik and Sharma (2008) defined it as an applied methodology, Sahoo et al. (2007) as philosophy and Dickson et al. (2007) defined lean manufacturing as a set of principles and techniques that leads to operational excellence and continuous process improvement through elimination of non-value added activities. The main objective of lean production is to develop appropriate strategies to eliminate waste by means of work-in progress (WIP), motion time, set-up time, lead time and defects while considering the economic needs of the problem (Sahoo et al., 2008).

VSM technique is the first stage of analysis used in most lean manufacturing implementation which provides a systematic approach for waste identification, lean tools selection and implementation (Vinodh et al., 2010; Alvarez et al., 2009; Singh et al., 2010; Grewal, 2008; Singh and Sharma, 2009; Singh et al., 2010; Domingo et al., 2007; Sahoo et al., 2007; Melton, 2005). Vinodh et al. (2010) has carried out VSM analysis to eliminate waste and enabling leanness in an Indian camshaft manufacturing organization. Poka-yoke, 5S, stage inspection, WIP reduction and IT-enabled logistics systems were implemented. As a result, idle time decreased from 19,660 to 19,449 minutes; Total cycle time has been reduced from 539 to 525 minutes, reduction of WIP inventory from 4,660 to 4,610 units, on time delivery improvement from 70% to 85% and 4% in defects. The redesign of an assembly line was presented with the objective of eliminating non value-added time and reducing the intermediate stocks through VSM, kanban and milkrun. The dock to dock time was reduced from 19.75 days to 17.1 days. Line rate increased from 0.38% to 0.44% and at the same time reducing idle times from the initial 32 to 10.9 hours (Alvarez et al., 2009). Singh et al. (2010) carried out a study on a piston pin manufacturing line showed that the Kanban system and electronic information flow gave positive results. Total inventory, Cycle time, Change over time, production lead time and total lead time showed significant reduction. Manpower also decreased from 12 to 10 persons. Implementation of Kanban-based system, Supermarket, Single Minute Exchange Die (SMED), 5S and kaizen in a leading manufacturer of bicycles also showed reduction in cycle time, lead time and value added time (Grewal, 2008). Lean tools such as kanban system and milk-run implemented in a crank shaft gear manufacturer (Singh and Sharma, 2009) resulted in the reduction of lead time, processing time, WIP and in manpower requirement. Other studies by Singh et al. (2010) on the shop floor of equalizer beam manufacturing line, Domingo et al. (2007 on an assembly line of the Bosch factory, located in Spain, Sahoo et al. (2007) in a forging company and Melton (2005) in the process industries all showed similar improvements.

3 Methodology

This study was carried out at a Plastic Molding Division of a SME company located in Malaysia.This organization is one of the leading manufacturers in automotive sound system. Running production at below capacity causes a big loss to the plastic industry. Each of the injection molding machines is dedicated for several customers. Therefore, model changeover time and product lead time play an important role to ensure manufacturers are able to fulfill the customers demand on various products within the short lead time. Failing to achieve the desirable status will lead to customer dissatisfaction. As a result, the company may lose the opportunity to gain more profit with the increase in demand and possibly, the future business. In some cases, manufacturers have invested on new machines to fulfill the increase in demand even though in actual fact that is not the sole solution to the problem. The plastic molding company is continually striving to increase productivity, even though OEE and output of their operations are still below the desired target.

The main goal is to satisfy the customer with the exact product quality, quantity, on time delivery and lower prices at the shortest lead time. An efficient production system can be achieved by a comprehensive approach to minimize wastes. This means eliminating over production, high inventory, redundant movement of material, waiting and delays, over processing, non-value added motion, high scrap and the need for rework. The current achievements for the company and its goals are shown in Table 1.

Table 1: Current and Targeted Performance

	Current	Targetted
Productivity	78.5%	92%
Stock Coverage	5.79 days	<5 days
Delivery	95.2%	100%
Model Changeover (200 tonnes machine)	160 minutes	45 minutes

The aims of this project are to develop current and future state of VSM for plastic injection molding operation, identify wastes and opportunity for continuous process improvement and then finally to adopt, test and analyses appropriate lean manufacturing tools.

The VSM approach which is based on five phases (Rother and Shook, 1998) was adopted. The product family, current state mapping, future state mapping, defining a working plan and achieving the working plan were selected. The Current state map was developed and analysed after collecting the relevant data. Various improvement proposals to reduce wastes of the operations have been formulated to develop the future state map. After the development of the future state map, various inferences that would improve the value of the processes have been derived for further actions.

3.1 *Product Selection*

The first step in this methodology is the selection of the critical product family. Data regarding all the product families were studied. Product selection is based on high production volume and values. Product P342 has been selected for the case study. The annual volume is 0.5 million pieces with a total value of RM695, 000 per year.

3.2 *Current State Map*

In order to produce only what the customers need, the supplier has to adapt the production quantity to the customer's orders and produce to the takt time. The takt time is used to synchronize the pace of production with the pace of sales. It is calculated by dividing the available working time per day by the customer demand rate per day (Rother and Shook 2003). The process flow is according to the standard control plan for plastic injection. A group of people from cross functional sections went for a plant tour, started at the opposite direction of the material stream that is from shipping to receiving. The first process in plastic injection molding is the drying process. The purpose of drying is to remove moisture content in plastic resin before further process. Dryness is important to ensure a common surface defect such as silver streaks does not occur during processing. The next process is injection molding. The process begins with setup process. Current practice of setup process takes at least 2 hours to complete. Setup instruction which contain important parameters such as temperature, speed, pressure, stroke, shot volume, and time is used as a guide to avoid trial and error practice. Upon completion of setup process, 2 shots of sample have been submitted for buy-off by QC technician. After the confirmation, production is allowed to run as per scheduled. For semi automatic operation, 1 headcount is allocated per shift to run the machine. For the big automatic part, 1 headcount per shift is allocated to perform visual inspection, deburring and packing. Another 1 headcount is allocated to collect and pack all small automatic parts. In-process inspection is performed every 3 hourly according to the inspection plan for every individual part. The main criteria are controlled dimensions and visual inspection. Finally, outgoing QC is performed every 2 hourly according to sampling plan for visual inspection.

The material flow and sequence of the main processes were sketched on a paper. The material flow from supplier to the main warehouse was done weekly based upon the requirement from customer. It is delivered to the plastic molding raw material store daily upon request. The plastic resin will be transferred to the centralized drying area using a manual pallet truck. After going through a minimum duration of 4 hours drying, plastic resin will be conveyed automatically to the designated machines based on type of plastic used for production. There are at least 5 types of common plastic resin used for production. They are ABS, PC, PA6, PA66 and PC+ABS. All molded parts will be sent to the outgoing QC area for final inspection. After that, molded parts will be kept temporarily in the plastic part store. Molded part will be sent to customer by electric pallet truck daily upon request.

The Information flow analysis is to understand the communication between logistic planners and raw material supplier; customer and manufacturer; and finally the internal communication within the department itself. Customer gives the order to the production controller through email. There are 3 types of information received from customer. Monthly forecast, weekly schedule and manufacturing order generated from the SAP system. Manufacturing order (MO) is automatically generated after the sales orders for final products are entered in the system and MRP runs during the weekend. The SAP system will also trigger the logistic planner on raw material requirements to produce the quantity as per manufacturing order. The available stock in warehouse and production area has been considered in the net requirement. The logistic planner will generate a purchase order and send it to the raw material supplier through email. The lead time is 3 months upon received the purchase order. Production controller requests the raw material from the warehouse in daily basis through email and telephone call. Production schedule are communicated personally to supervisor and the team during daily production meeting.

Process, material and information flow have given a partial overview of the whole process cycle. At this stage, number of inventory or WIP has been counted throughout the product flow and recorded in the value stream map. The raw materials, work in products and finished products are considered as an asset that is ready for sale. Inventory represents one of the most important assets because the turnover of inventory represents one of the primary sources of revenue generation and earnings for the company. Total stock coverage for p342 is 8.15 days. Raw material stocks in the main warehouse, internal store and drying area contributed 3.72 days or 45.6%. Finish products at molding machine contribute 1.3%, outgoing inspection 2.2%, internal storage 43.9% and finally at customer side contributed 7.0%. All the information gathered are combined to complete the current state mapping for further analysis. Process flow, material flow, information flow, data boxes and inventory triangle are combined together. **Figure 1** shows the complete current state mapping of the selected product. Finally, lead time and value added time are calculated and included in the current state of value stream map.

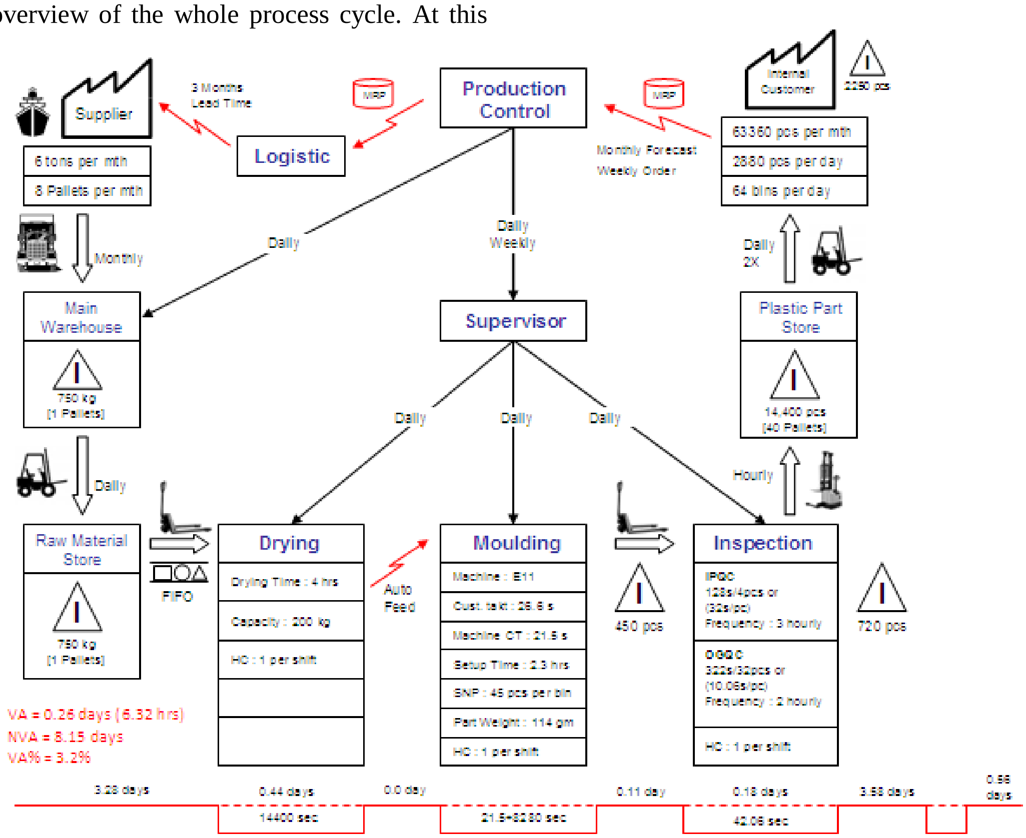

Figure 1: Current state map

3.3 *Future State Map*

Process Based on the observation during genchi gembutsu, all types of waste were identified. Wastes of waiting, motion and transportation have significantly contributed to the longer setup time. First, the technician was seen waiting for the temperature of the hot runner system to increase before proceeding to the sample production. Second, the technician has to wait for the QC technician's decision on the setup sample. The inspection took at least 30 minutes to complete. He also spent unnecessary time to search for screws and tools during setup and transported the new mold only after the machine was stopped for model changeover. High inventory was observed at the workstation and storage area due to the batch production concept. Complete monthly quantity was produced with only one time setup. The next model was also followed the same concept. Sometime, the produced quantity is more than the targeted monthly quantity. The highest stock was observed in Plastic part store as compared to other areas and processes. According to the production officer and planner, the high stock was kept in the storage area to support the high demand from customer. Sometimes, it will remain until the next month if the customer does not pull the part due to unexpected problem at their side. In case of quality complaint, the whole lot was pulled back for rescreening and sometime all ended up to the scrap bin. The workstation layout was appropriate. No obvious problem was observed on operator ostures and hand motion. However during packing process, the operator has to walk 50 meters to get empty containers which were located outside the building. The completed parts were placed at the back of operator sitting area and later on transferred to outgoing QC area for final inspection. This unnecessary transportation was performed by the material handlers every 1 to 2 hours. After inspection, the accepted lots were transferred to plastic part store for temporary storage. Molded part will be sent to customer using electric pallet truck daily upon request. The delivery was completed after few rounds as it covers all plastic part requested at the same time. Appropriate tools for improvements were identified based on lean tools application by Vinodh et al. (2010), Alvarez et al. (2009), Singh et al. (2010), Grewal (2008), Singh and Sharma (2009), Domingo et al. (2007), Sahoo et al. (2007) and Melton (2005) as described in the literature review. To improve or eliminate waste of overproduction and inventory, small lot size, heijunka, kanban pull, milkrun and supermarket are proposed for implementation. 5S, SMED, relayout and standard work are proposed for elimination of waste due to long waiting and motion.

The team focused on any opportunity for continuous improvement process process (CIP) at every possible area in the value stream map. Consignment warehouse is the best choice for raw material storage. The supplier places some of their inventory in customer warehouse and allows them to consume directly from this stock. The customer purchases or pays the inventory only after consumption. 5S is the best practice in any of the improvement projects. In this case, 5S is needed at the drying and production areas. SMED focused on quick changeover to allow flexibility and more variety of parts produced. Relayout and standard procedure helps to improve process flow and unnecessary motion or transportation. Kanban, heijunka, milkrun and supermarket will be implemented for the selected machine to test their effectiveness in reducing inventory. Last but not least, small lot size can be immediately implemented on all products without further testing. Future state of value stream mapping is constructed to visualize the goal of the project. The goal for stock coverage is 5 days, changeover time is 45 minutes, Delivery attainment is 100%, productivity is 92%, and quality is 1000ppm and finally production scrap less than 0.5%. The total plan lead time is 2.49 days and the value added process is 4.77 hours. **Figure 2** shows the future state map that the company would like to achieve.

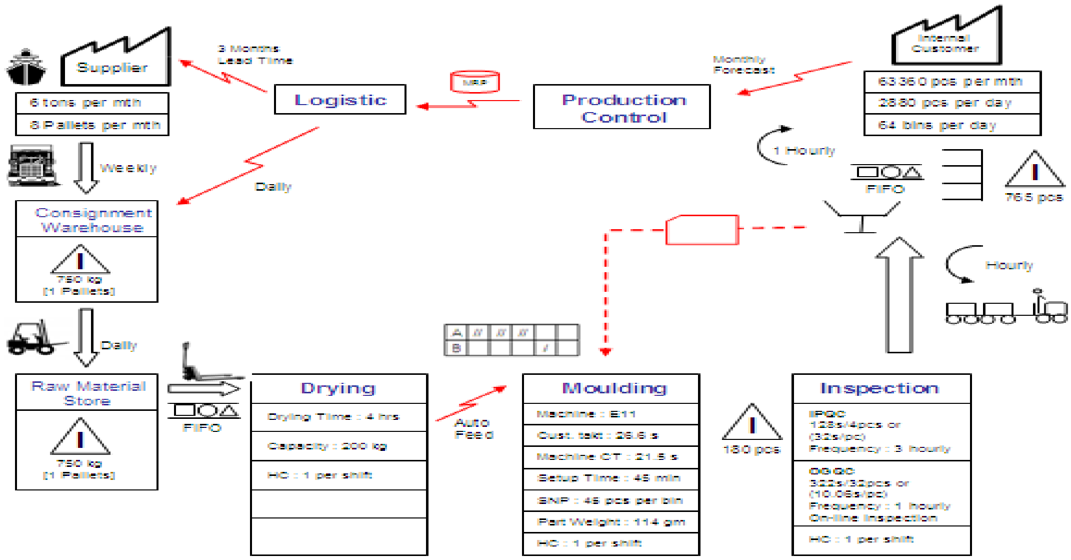

Figure 2: Future state map

4 Result and discussion

The first step of waste elimination project was to ensure that the production area is free of all unwanted items, equipment and workstation are neatly arranged, production floor and its surroundings are clean and all the hidden items or problems are visualized. For this reason, 5S principles are implemented on the shop floor. All unnecessary tools, parts, and instructions are removed. Only essential items are kept and prioritized as per requirements and keeping them in easily-accessible places. Everything else is stored or discarded. There should be a place for everything and everything should be in its place. The place for each item were clearly labeled or demarcated. Items have been arranged in a manner that promotes efficient work flow, with equipment used most often being the most easily accessible. The workplace is well-kept and organized. At the end of each shift, the work area are cleaned and everything are restored to its place. This makes it easy to know what goes where and ensures that everything is where it belongs. A key point is that maintaining cleanliness has been a part of the daily work. It is not an occasional activity initiated when things get too messy. Work practices in most of the workstations are kept consistent and standardized. All employees doing the same job are able to work in any station. Everyone knows exactly what his or her responsibilities are for adhering to the first 3 S's. The standard is established, maintained and reviewed regularly. Audit checklist is used for auditing purpose to ensure the standard is sustained and adhered at all times.

Prior to SMED implementation, Set-up time data for each group of injection molding machines are verified and compiled. It is observed that that the 100-200 ton group 1 machines took the longest time for setup as compared to other group of machines. Therefore, this group of machines has been selected for further study. During preliminary stage, Internal and external activities are not distinguished. Stop watch was used to verify actual time for the individual activities and the whole operations. The setup process was performed by one technician. Setup tools and overhead crane was used to assist the technician for setting up and taking down the mold. All activities, movements and tasks were recorded into the recording sheet. Total setup time was 2.66 hours. Setup activities are distinguished and classified as internal and external activities. External activities are done while the machine is still running the previous model. Internal activities takes place after the machine stopped for model changeover until the first good part of the changed model is produced. All activities that can be performed externally are never performed internally. Five activities have been are identified as external activities: i. Checking production plan for model changeover, ii. Taking product file from cabinet, iii. Taking new mold from storage area, iv. Pushing the new mold to machine, and v., Pushing smed trolley to machine. By converting internal to external activities, the activities have been re-examined to see whether any steps have been wrongly assumed to be internal. Based on the analysis, another 5 activities were identified for the conversion to the external activities: i. Looking for nozzle tip, ii. Temperature controller and hot runner controller, iii. Looking for indirect clamp, Allen key and bolts, iv. Getting the ejector coupling from cabinet, and v., Writing the tool down report and pushing the mold to storage area. The first step of streamlining process was the introduction of a second technician to perform the setup task parallel to both sides of the injection molding machine. As a result, Setup time has been reduced from 160 minutes to 58 minutes.

The improvement plan has been drafted out and implemented successfully to reduce setup time. The first action was the implementation of the new SMED trolley which was designed to assist the technician to carry out their task efficiently. Searching of tools was eliminated. Visual management allows technician to know any missing tools and prepare before changeover. The next action taken was the standardization of machine nozzle, sprue bush and mold Locating Ring. Adapter ring is introduced to expedite the changeover process. The permanent coupling of mold cooling channel allows the technician to connect only 1 hose for inlet and 1 hose for outlet. This solution saved at least 5 to 8 minutes of setup time. The Quick mold clamp eliminates the use of bolts, direct and indirect clamps. This system saved at least 10 to 15 minutes of setup time. Quick robot adaptor eliminates the use of screws, saving at least 5 minutes. Using Color identification on water connector eliminates wrong connection and searching time. Red paint was used for water outlet and blue for water inlet. Crane centering marking allows technician to move the crane and stop at the exact location.

The new setup process was observed. This time it was performed with additional improvement on standardization and a new SMED trolley. The new checklist and changeover plan have been introduced. It contains the detail of machine layout and the movement of both technicians. The setup process runs smoothly without major discrepancies on standard procedures and technician movement. No searching for setup tools was observed and everything has been prepared upfront before the changeover process started. Setup buy-off has been performed based on part weight and visual inspection. Both criteria are sufficient enough to be used as a guideline to release for production. Most of the time, dimension will be in order if the part weight is according to the standard setup instruction. Hot runner system was switched on before the new mold is tightened. This has reduced the waiting time for the temperature to increase to the operating temperature. The setup buy-off only took 10 minutes compared to the earlier practice which took at least 20 to 30 minutes. However, the dimension check was not neglected and continued after the confirmation given to run production. The initial setup process took at least 2.66 hours for completion. After transferring the initial internal activities to external activities to reduce the changeover time and using parallel operation has reduced the setup time to 58 minutes. Standardization activities and quick process tools finally reduced the changeover time to 33 minutes. SMED techniques have been implemented across the board on all products and machines. The monitoring of setup time and frequency indicates overall improvement with an average of 215 setups per month compare to the previous year which was 171 setups. Average setup time for the high tonnage machine was 38.5 minutes. The increase in changeover frequency was 25.7%. Overall improvement on changeover time is 76% as compared to the initial time of 160 minutes. Shingo (2000) reported maximum of 30% reduction at the 1st stage, 75% at 2nd stage and up to 90% after the final stage of SMED implementation. The result is slightly lower as compared to Grewal (2008) who has achieved 81.5% reduction, but better than Singh et al. (2010) who has only achieved 6.75%. However, overall result has shown a positive trend in changeover time reduction. SMED has provided a platform which enabled for a frequent changeover activities and produces a variety of product to support various customers.

The good achievement in SMED or changeover time allows the implementation of leveled and small lot size production. Heijunka and small lot size production utilize quick changeover to produce variety of products or the same model at smaller size. This will ensure fulfillment of various customer demand, low inventory and scrap if the lot is rejected due to quality issue. Production schedule was leveled over an interval of time in order to achieve smooth flow and be better synchronized with the actual customer demand. The selected machine runs 2 models, p342 and p049. Model P342 requirement is 2880 pieces or 64 bins per day. Model p049 requirement is 560 pieces or 28 bins per day. The next step of leveling process was to determine number of changeover and planned schedule for production. Remaining time was calculated by subtracting break time, loss time and requirement capacity from the total available capacities. Therefore, the EPEI (every part every interval) which indicates the time span of each model and pattern was determined as one. That mean, the daily production pattern will start with model p342 and then model p049 with 2 times changeover. The same pattern will continues daily until the next production pattern is determined. One shift production on Saturday is used to recover the backlog from normal production. Other products which do not involve in production leveling have been subjected to a small lot size practice. The old practice of batch production leads to high inventory, high scrap and low flexibility. More changeovers have been introduced in the daily production with a smaller lot size planned according to customer requirement date.

Kanban system has been implemented on the selected parts as described previously in production leveling exercise. Daily production was based on leveled production. At the beginning of production, kanban cards are collected by operator from the heijunka board. Then, it will be attached to each of the bins containing finished products. Every hour, milkrun truck will collect all the accepted lots from production floor and deliver to customer. At customer side, finished goods bins are loaded to the supermarket at the designated area. Upon consumption of finished goods bin, kanban card will be placed inside kanban post by customer. Kanban cards are collected hourly by milkrun driver after the delivery to the supermarket. The accumulated kanban cards will be launched again for the next day following the same pattern. The monitoring is done on model p342 to evaluate the effectiveness of kanban in reducing inventory. The counting has been carried out at all locations at 6.00pm every day. Average stock coverage was 0.7days as compared to 4.87 days excluding plastic resin stock as stated in value stream map. Overall stock coverage contributed by the implementation of lean manufacturing tools was 2.86 days. Overall delivery attainment has shown an improvement from 95.2% to 100%.

Relayout of production floor and improvement of material movement and workstation have also contributed to the better efficiency of the shop floor activities.

- Outgoing inspection area has been eliminated. The buy-off will be carried out at the workstation. Good part will be identified by “QC Accepted” stamp.
- Milkrun driver will collect the accepted finished products hourly at the workstation and deliver directly to customer supermarket or warehouse.
- Empty container storage area has been relocated to production area. Walking distance reduced from 45 meters to 20 meters.
- After the delivery, all empty containers will be collected and sent back to the new storage area. This cycle will be continues every hour.
- WIP area has been relocated beside the operator workstation. Walking distance reduced from 20 meters to 5 meters.
- Wireless paging system is introduced. Operator just needs to press one button to call the technician to the relevant machine or workstation. Walking and searching is not required. The signal from the button will be directed by receiver to the technician’s pager wherever they are in the plant. The pager will display the location of the machine for fast response.

As a result of the above implementation, operators are able to concentrate on their work tasks with a minor movement. It helps to increase operator effectiveness and productivity. Milkrun helps to reduce the material handler burden so that the delivery and collection of empty container could be done only in one cycle. Previously, the material handler has to go for few rounds to perform the same task due to insufficient handling capacity of electric pallet truck. The result shows a very significant improvement on changeover time. The reduction of 76% allows for more changeover and increases machine flexibility to produce variety of parts with smaller lot sizes. Number of mold changeover has increased from 171 times per month to 215 times (25.7%). As a result, stock coverage has been reduced from 5.79 days to 2.86 days (50.6%) and delivery achieved 100% for every month. Overall productivity has shown 15.6% improvement which indicates the effectiveness of direct headcount and the whole operations. The project findings showed similar trends as achieved by most of lean practitioners and researchers. Singh et al. (2010) manage to reduce setup time from 711 sec to 663 sec, inventory reduction by 89.47% and achieved productivity increment by 42.76%. Peter and Lanza (2010) have achieved inventory reduction by 56%

and productivity up to 14%. Vinodh et al. (2010) has improved on time delivery from 70% to 85%. Inventory reduction was also reported by Singh and Sharma (2009) with reduction from 53.31 days to 4.11 days and Melton (2005) with reduction of 30%.

5 Conclusions

The aims of this project were to achieve higher productivity, lower changeover time, lower inventory and on time delivery. The process flow of plastic injection molding and the standard operating procedures have to be carefully understood. The development of the current state map was crucial because it helps to visualize the actual process and provide all relevant information related to plastic injection molding operation. The systematic approach allowed for identification and selection of appropriate lean tools for process improvement. The future state map is not the end of value stream activities. It should be revisited from time to time as a part of continuous improvement process. A new type of waste could be introduced as the new improvement project is executed. The practice of batch production has been changed to smaller lot size according to the customer requirement date. Waste of transportation and motion were identified and improved accordingly.

Lean manufacturing can be adapted in any manufacturing sector. In this project, 5S, SMED, small lot size, milkrun, layout and standard procedure improvement were finally applied to the entire production area and products. However, heijunka and kanban implementation only involves 2 products. The results achieved in this project showed significant improvements in the overall performance of plastic molding operations which allows it to be more productive, flexible and profitable.

LIMITATIONS AND FUTURE RESEARCH DIRECTION

The implementation of Heijunka and Kanban system has been carried out on one machine and involves only two products. Therefore, the problem observed may not be enough to reflect the actual difficulties faced by some of practitioners. The inconsistency and sudden increase in customer demand has been observed on most of the products. Frequent revision of customer order within a month may lead to high variation and could ruin the whole project plan. However, future research direction could be expanded to the other machines that have variety of products with several high runners and exotic parts in consideration. Apart of heijunka and kanban system, the research could also focus on minimum setup quantity (MSQ) or economic production quantity (EPQ).

Even though small lot production is effective in reducing inventory, small lot size and frequent changeover in plastic injection molding could lead to unexpected losses. Material wastage and cleaning material usage will increase proportionately according to changeover frequency. Labor cost will increase as the number of changeover increases due to additional headcount requirement. Repair and replacement cost incurred due to wear and tear of mold and machine parts. Lost production cost as a result of machine non productive time, energy cost and other type of losses have to be considered in future research. Cost analysis and qualitative comparison could be used to determine the best practice for plastic molding operation.

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