Material and Information Flow Chart (MIFC) Mapping for Lean Manufacturing Implementation in the D55D Assembly Line

1) Nurul Hayati Binti Abdul Halim
2) Ahmed Bin Jaffar
3) Noriah Binti Yusoff
Faculty of Mechanical Engineering
Universiti Teknologi Mara, Shah Alam, Malaysia
1) ned_jun@yahoo.com 2) ahmedjaffar@salam.uitm.edu.my,
3) noriahyusoff@salam.uitm.edu.my

Abstract

This research paper is to demonstrate the adoption of the Material and Information Flow Chart (MIFC) in implementing Lean Manufacturing (LM) at an automotive component assembly line in Malaysia. MIFC is one of the lean tools, also known as Value Stream Mapping (VSM). It is widely used as a framework for systematic and structured improvement activities in LM implementation. In addition, MIFC is a versatile tool to scrutinize in detail relationships between materials and information flows from the beginning until the end of the assembly process. A case study was conducted at an automotive component assembly line, at XYZ Manufacturing Sendirian Berhad. The MIFC was used as a means to map how the materials and information were delivered along the system, in visualizing the studied area. Findings show that MIFC is an effective tool in identifying wastes and source of the waste, areas for improvement as well as appropriate tools for Kaizen activities.

1. Introduction

The process of structuring, operating, controlling, managing, and continuously improving industrial production systems is commonly associated with Lean manufacturing philosophy [1]. LM is the American term for what is known as Toyota Production System (TPS) [2]. This philosophy is defined as a process of optimizing the existing production activity based on customers' need by identifying and understanding the customers' values [3]. Hence, it is characterized as customer focused, eliminating waste, creating value, dynamic and continuous [4].

LM was based on Toyota Production System (TPS) which was developed by Toyota. The term Lean Manufacturing was first coined by John Krafcik in a Fall 1988 article "Triumph of the Lean Production System", and it was popularized by James Womack, Daniel Jones, and Daniel Rose in their book ''The Machine That Changed the World''. Based on this book, the system was then named "Lean Manufacturing" [5].

LM or TPS is not new to most automotive components assemblers in Malaysia. They were first initiated by manufacturers from Japan, such as Toyota, Kayaba and Honda. Then, it was followed by local car assemblers such as Proton, Perodua and their suppliers. The reasons why it was applied may vary but it was executed with the same objectives which include on-time delivery, to maintain quality, to increase profit by reducing operations costs and to remain competitive in the local as well as global markets. Concluding, the main goals of LM are cost reduction and improvement of productivity, with focuses on activities such as eliminating waste, reducing inventory and continuous improvement [5], [6], [7], [8].

Thus, this research seeks to identify all wastes and source of wastes as classified in the LM philosophy and to implement appropriate lean tools for improvement activities in the D55D assembly line.

2. Literature review

In LM, waste is defined as anything related to the process that adds cost but does not add value to the final product produced [9]. Waste elimination is one of the LM's goals and it is believed to be one of the most effective ways to reduce the production cost and increase the profitability of many companies. Some of the examples of wastes elimination activities are elimination of defects, unneeded transportation, waiting time, rejects and non-value-added activities such as rework, recheck and marking process [10], 11]. To eliminate waste, it is important to understand what waste is and source of the wastes [12].

The seven wastes were initially identified almost 50 years ago by Toyota's Chief Engineer, Taiichi Ohno during the development of the TPS [8]. They were classified as: i) transportation; ii) inventory; iii) motion; iv) waiting; v) over processing; vi) over production; and vii) defect. Ohno believed that these wastes account for up to 95% of all costs in non-Lean Manufacturing environments [5]. This statement was reinforced by the Lean Enterprise Research Center, Cardiff, UK, through their research which concluded that, for a typical physical product environment, 5% of the total activities were value-adding activities (VAA), 60% were non-value-adding activities, and the remaining 35% are necessary but non-value adding activities (NNVAA) [1]. Since non-value-added activity (NVAA) is a waste, many manufacturers who are aware about this matter strived to eliminate as much waste as possible in their system.

The effectiveness of LM is supported by a set of lean tools such as Kanban system, Standardized Work (SW), MIFC/ VSM, Total Productive Maintenance (TPM), Single Minute Exchange of Dies (SMED), Continuous Flow Manufacturing System, Kaizen, 5S, Heijunka system and others [13].

MIFC is the most widely used tool in LM implementation. This tool was created also by Taiichi Ohno, who is the creator of the TPS and Kanban system in Toyota [5]. MIFC was used to teach TPS and lead major TPS projects in Toyota. Its main function is to visually represent the flow of material and information on individual processes. Originally, this tool was passed on within the company through the learning by doing, without any standard document on how to develop a MIFC. Eventually, this idea was put forward and formalized by Rother in his book "Learning to See", which teaches the methodology on how to exploit this tool and named it Value Stream Mapping (VSM).

Therefore, most manufacturers, journals and books use the terms Value Stream Mapping (VSM) to demonstrate this tool instead of MIFC, which was used by Toyota and its' suppliers only. This research was done by Toyota Assembler Team, thus the MIFC term and methods will be used rather than VSM.

Both tools, MIFC and VSM have similar functions and serve the same purpose except for some differences in the iconic illustrations during the mapping process. They are rated as one of the most efficient visual illustration mechanism in capturing the current state of the system, identifying the long term vision, and developing a plan to get the target [7], [14]. In VSM, lead time for each process is shown at the bottom of the map, in the form of total lead time for the process. Whilst in MIFC, lead time and related information about the process such as working time and shift operation are located at the top of the map. The lead time is broken up further into three difference categories; namely process, information and physical stock lead times. Therefore, detailed information about the process can be easily accessed via MIFC.

3. The Case Study Subject

The case study area for this research is D55D assembly line. This line produces automotive air filter systems to be delivered to Perodua. The line runs on 12 hour shifts, all year long except for public holidays and major shutdowns. The line is a semi-automated production with manual loading and unloading at the beginning and the end of the process. There are two operators in this line, which is in workstation 1; assembly machine and workstation 2; the inspection machine. During the process, the operator has to assemble all the relevant components on the plastic case manually, and then it was fitted or clamped using an assembly machine. Inspection of the completed part is performed by the inspection machine.

Material transfer or loading and unloading process were done by a material handler in large quantities according to the production order. For large components, wire-mesh is used as temporary storage in the assembly line to reduce the frequency of loading and unloading processes. In addition, the small components were supplied in large quantity and also according to the production order.

Production is run according to production orders provided by the planning department on a weekly basis. When the orders arrived, the production supervisor will refer to the production schedule to route the order. The production schedule is prepared by the production planner on a monthly basis. This schedule is used as a reference point by the production department to monitor their weekly and daily production outputs and variations in fulfilling the customer's order. The schedule usually will be updated further on as needed according to daily requirement schedules.

4. Methodology

This is a case based research; therefore data were gathered through the following process. Observation were done during normal production time with the aid of documents such as Standard Operating

Procedures (SOP), existing Process Flow Chart (PFC), Daily Production Report (DPR) and conversation with the production engineer and line leader. Data collection was conducted by using stop watch and video recorder and by referring to Production Control System (PCS) to collect previous data and Bill of Material (BOM) for data comparison. For cycle time analysis, time study method was used according to the method introduced by Frederick W. Taylor [15]. Then, standard cycle times and takt time for the studied line were calculated. These data were then used during line analysis, mapping current MIFC and data comparison. Current MIFC for D55D assembly line is as shown in Figure 1.0 and improved MIFC in Figure 2.0.

The MIFC of the existing operation reveals that, the existing system is practicing Push manufacturing system. The production is run based on work order given by the planner. The line takt time is 69.20 secs, which is way above the targetted takt time. This resulted in high overtime and large inventories before and after the assembly processes. Bottlenecks also occured in between the workstations which means continuous flow was not applied along the process. It was also observed that production took about 3.23 days to fulfill the order generated by the planning department. On top of that, the rejection cost at the both workstation and the breakdown time, to a large extent was very high. In terms of productivity, it was targeted at 50 pc/man hour but the actual performance was only at 42.0 pc/man hour.

5. Waste identification

There are a lots of wastes which were identified in the system. Kaizen Point Check Sheet (KPCS) was used to document all the wastes and areas that were identified for Kaizen as in the Table 1.0 below

Table 1.0: Kaizen Point Check Sheet (KPCS)

Kaizen Point Check Sheet (KPCS)			
Line:	D55D assembly line	**Operators:**	Kong/ Hasri
No.	**Types of waste**	**Areas**	**Description**
1.	Transport	Material handler	Rules of conveyance for material handler (components and finished good) were not established.
2.	Inventory	Outgoing bay	Large FG producing temporarily stored at outgoing bay waiting for inspection.
3.	Motion	Assembly line	Large stock of components and plastic parts as it was supplied in large quantities.
		WIP Table	High stock in-process created a bottleneck between the workstations.
		Assembly line	Lots of back and forth movement due to poor layout and large size storage used in the assembly line.
4.	Waiting	Assembly line	Packing area too far from the work station due to poor layout.
		Material handler	Shortage of material due to poor supplier system.
5.	Over production	Machines	Machine breakdown frequently. Therefore, production creates safety stocks and run production on weekends to avoid backlog.
6.	Over processing	Inspection machine	Re-run inspection process due to unstable machine condition.
		Assembly machine	Marking on part as confirmation due to unstable machine condition.
7.	Defect	Injection line	Poor plastic parts quality from the injection line.

Through losses analysis, losses percentage in workstation 1 is 16.25% with 84.62% from the losses came from NVAA. While for workstation 2 is 18.38% with 81.63% from the losses came from NVAA. Through data collection and observation, the following conclusions were made:

i. Takt time is not being used at the production area.
ii. No standardized work applied at line and operators performed their task without fully adhering to SOP.
iii. Operators frequently stopped production due to materials shortage and machine breakdown.
iv. Large FG produced and was temporarily stored at outgoing bay, waiting for delivery.
v. Large stock of components and plastic parts at the line due to large quantities supplied.
vi. The production line is operating on a Push system and limited continuous flow.
vii. Bottleneck occurred between workstations with high work-in-process stock at the line.
viii. Rejected components due to poor quality of plastic parts from injection line.
ix. Packing area is too far from operator at workstation 2.
x. There are lots of non-value added activities such as re-inspect, re-check, marking and rework process due to unstable of machines condition.

Current Material and Information Flow Chart (MIFC) at D55D Assembly Line					
Items	Components	Assembly process	Inspection process	Total Lead Time (min)	
Shift operation	2 Shifts + 2.5 hrs OT	1 shift + 2.5 hrs OT	1 shift + 2.5 hrs OT	-	
Working time	8 am to 8 pm	8.00 am to 8.00 pm	8.00 am to 8.00 pm	-	
Information lead time	615.00 min	615.00 min	0.00 min	1230.00 min	2.000 day
Process lead time	10.00 min	8.07 min	1.35 min	19.42 min	0.032 day
Stock lead time	334.91 min	0.00 min	402.16 min	737.07 min	1.198 day
Total lead time	959.91 min	623.07 min	403.51 min	1986.49 min	3.230 day

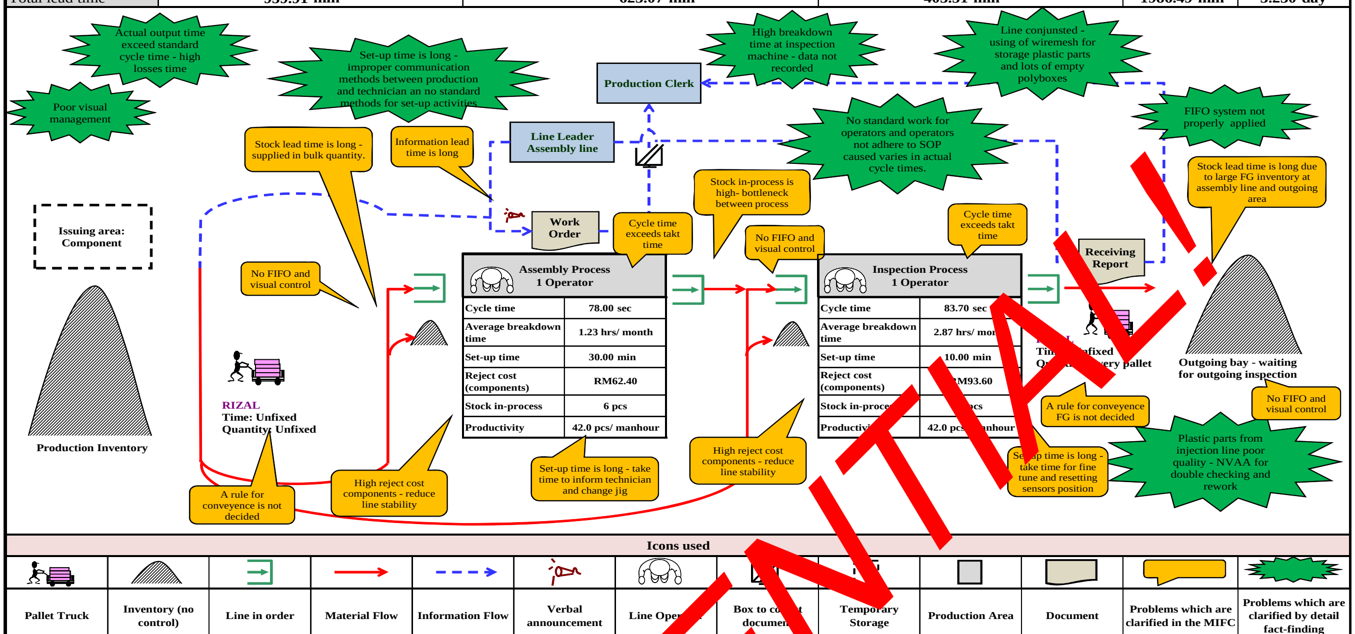

Figure 1.0: Current MIFC for existing D55D assembly line

Improved Material and Information Flow Chart at D55DAssembly Line					
Items	Components	Assembl[illegible] proces[illegible]	Inspection process	Total Lead Time (min)	
Shift operation	1 Shifts + 2.5 hrs OT	1 shift + [illegible] hrs OT	1 shift + 2.5 hrs OT	-	
Working time	8 am to 8 pm / 8 pm to 8 am	8.0[illegible] am to [illegible]0 pm	8.00 am to 8.00 pm	-	
Information lead time	15.00 min	126.87 [illegible]in	0 min	141.87 min	0.231 day
Process lead time	5.00 min	1.15 [illegible]	1.15 min	7.30 min	0.012 day
Stock lead time	30.00 min	0.00 mi[illegible]	155.7 min	185.70 min	0.302 day
Total lead time	50.00 min	[illegible].02 min	156.85 min	334.87 min	0.545 day

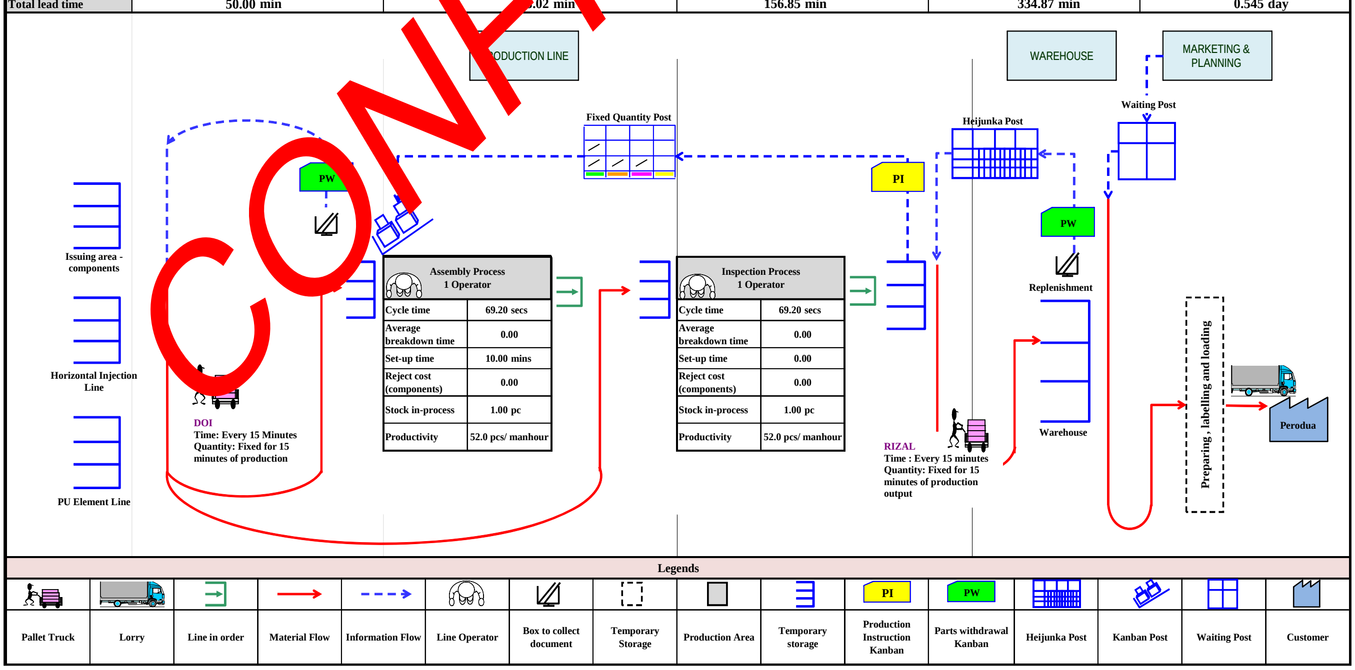

Figure 2.0: Improved MIFC for future D55D assembly line

6. Improvement activities

Before the improved MIFC was mapped, a set of Lean metrics had been identified for the case study area. Lean metrics or also known as lean parameter is the most common tool used by many manufacturers to measure and monitor the impact of implementing LM techniques in their company [11]. It is used as a guide for the team to achieve its target and it helps to drive continuous improvement and waste elimination. For this research purposes, the lean metrics such as product lead time, quality, cycle times, capacity, overtime, breakdown times, continuous flow manufacturing system and shop floor area were adopted. All the metrics were documented in Cell Kaizen Target Sheet (CKTS) as shown in Figure 3.0. Target for the metrics was set based on the company's targets which is to run the product at or less than the takt time. Then, improved MIFC was designed and mapped as shown in Figure 2.0. A new system was designed with the implementation of Kanban system to visualize their long term planning

The new target line cycle time is 69.2 secs per piece, which is equal to minimum line takt time. It is based on the maximum fluctuations of monthly volumes at this line. From the cycle time, target lead time from the improved MIFC was calculated as 0.545 days or equal to 83.13% reduction from the existing lead time. To achieve these targets, seven major improvement activities were implemented which were:

i. Simplify and re-arrange the assembly processes to reduce permanently current cycle times so the production would run below the takt time.
ii. Elimination of NVAA such as arranging poly-boxes and wire-meshes, double checking and marking process through Kaizen activities.
iii. Workload balancing to balance the workloads between workstations as well as to minimize in-process stock and eliminate bottleneck process.
iv. Reduction of operators' movements; on hand movements and walking by combining and eliminating the movements with application of gravity flow rack system and training the operators on how to use both their hands simultaneously.
v. Introduction of gravity flow rack system to present the parts and components as close as possible to the operators' point of use, to guarantee First in First out (FIFO) system as well as reduced components stocks quantity in the line.
vi. Line re-layout with application of continuous flow manufacturing system and in U-shape cell to improve line balancing and maximize communication between operators.
vii. Eliminate stability issues such as machine breakdown and quality problem through detailed root cause and countermeasures analysis by using 5-Why methods.

7. Results and discussion

The results after the implementation were collected and analyzed. These activities were conducted after the implementation was fully settled and stabilized as well as the line performance had achieved the set target. Cell Kaizen Target Sheet (CKTS – Figure 3.0) was used to perform results comparison on the metrics used.

From the CKTS below, it was revealed that after all the improvement activities were carried out, the total lead time was reduced by 83.50%, which is from 3.23 days to 0.533 day only. This is a result of the reduction of line cycle time as well as inventory levels at component, assembly and inspection process. During data collection on the improved line, it was found that 3.20 seconds of the non-value-added time had been eliminated from the assembly time. At workstation 1, NVA in form of periodical tasks has been drastically reduced by 77.3% which is from 11.00 sec to 2.5 sec only. While at workstation 2, it was reduced by 68.35% which is from 7.9 sec to 2.4 sec.

Cell Kaizen Target Sheet (CKTS)					
Line	D55D assembly line	**Period of project:**	3 months		
Metrics		**Existing**	**Target**	**Results**	**% Increase/ Decrease**
Lead time (day)	Components	**1.56**	0.081	**0.079**	94.94% Decreased
	Assembly process	**1.01**	0.208	**0.208**	79.41% Decreased
	Inspection process	**0.66**	0.255	**0.245**	62.88% Decreased
	Total	**3.23**	0545	**0.533**	83.50% Decreased
Line cycle time (secs)		**80.70**	69.20	**66.50**	17.60% Decreased
Quality (RM)		**RM 156.00**	RM 0.00	**RM 0.00**	100% Improved
Manufacturing capacity (pcs/ shift)		**476.07**	530.00	**567.70**	16.14% Improved
Overtime (total manhour/ month)		**378.0**	150.0	**85.0**	77.51% Improved
Breakdown time (hours)		**4.10**	0.00	**0.00**	100% Improved
Continuous flow manufacturing system		**No**	Yes	**Yes**	100% Improved
Shop floor area		**22 m³**	15 m³	**18 m³**	18.18% Decreased

Figure 3.0: Completed Cell Kaizen Target Sheet (CKTS)

In terms of quality, rejected components were eliminated after the stability and quality issues were solved. Manufacturing capacity increased by 16.14% which is from 476.07 to 567.70 pieces per shift. With the existing capacity of 500 pieces per shift, this extra capacity will allow the order volumes to increase in the future to generate more sales. At the same time, it enables the company to meet its daily volume requirements without unplanned overtime especially on weekends as is usually practiced at the existing case study area. Result shows that, overtime was successfully reduced by 77.51% which is from 378.0 to 85.0 man hour per month only. For the breakdown time, it was eliminated through root cause and countermeasures analysis on the stability issues at both machines. With the aid of gravity flow rack system and line balancing, the line successfully implementing continuous flow manufacturing system with the reduction in shop floor area.

With the reduction of line cycle time, hourly output increased at which proportionally increase the profitability, performance, efficiency, and effectiveness of the improved case study area. Consequently, productivity increased by 22.22%, which is from 42.00 pieces per man hour to 54.00 pieces per man hour.

8. Conclusion

The implementation of LM system by means of MIFC and other lean tools in a D55D assembly area proved that MIFC is a powerful tool for effective implementation of LM. It helped to visualize the existing study area in the forms of material and information flows. Through the tool, wastes and source of wastes in the system were systematically identified together with the identification of appropriate lean tools for Kaizen activities. Through the researchers experience during the implementation, it was observed that this tool helped in terms of allowing people in the company to understand more clearly about their production system. Moreover, clear communication between management and workers on the expectations and the set targets from the implementation of the Kaizen activities was executed successfully. With the great achievements in the following areas such as lead time, cycle time and over time reduction, shop floor reduction as well as introduction of continuous flow manufacturing system, it can be concluded that, through deeper understanding on the existing condition of the study area, proper planning and application of appropriate lean tools; , MIFC was successfully helped to eliminate most of the identified wastes in the case study area. However, to maintain all the improvements and stability of the improved line, it is suggested that the company takes some additional actions such as:

i. To apply Total Productive Maintenance (TPM) at the line, to maintain the stability and efficiency of both machines.
ii. To implement Taguchi's method of parameter design especially at injection molding area, to solve quality problems at the line as well as reducing the tendency of the rejected parts from escape into the next process.
iii. To improve production visual management to enables employees and management to quickly and easily grasp latest situations at the production area.
iv. Continuous support from management to encourage for continuous improvement at the line; and
v. Standardize the new assembly process through proper documentation.

9. Reference

[1] A. Sahoo, N. Singh and R. Shankar, (2008). "Lean philosophy: implementation in a forging company." The International Journal of Advanced Manufacturing Technology 36(5): 451-462.
[2] A. C. Laraia, P. E. Moody, R. W. Hall (1999), "The Kaizen Blitz, Accelerating Breakthroughs In Productivity and Performance", John Wiley and Sons: 242-250.
[3] J. Heizer and B. Render (2006), "Operations Management", Pearson International Edition, Eight Editions: 13-15, 403-406.
[4] R. Ritchie and J. Angelis (2010), "Implementing Lean into a Servicing Environment", Advances in Production Management Systems. New Challenges, New Approaches. B. Vallespir and T. Alix, Springer Boston. 338: 587-594.
[5] A. Badurdeen (2007), "Lean manufacturing basics", http://www.leanmanufacturingconcepts.com.
[6] R. A. Kasul and J. G. Motwani (1997). "Successful implementation of TPS in a manufacturing setting: a case study." Industrial Management & Data Systems 97(7): 274-279.
[7] M. Rother and J. Shook (1999)," Learning to see, value stream mapping to create value and eliminate muda (foreword by Jim Womack and Dan Jones)", Version 1.2: 9 -19.
[8] M. F. William (2001), "Lean manufacturing, Tools, techniques and how to use them", The CRC Press series on resource management: 4-19.
[9] D. Tapping, T. Luyster and T. Shuker (2002), "Value Stream Management, Eight Steps to Planning, Mapping, and Sustaining Lean Improvement", Productivity Press: 27-31, 113.
[10] L. N. Pattanaik and B. P. Sharma (2009). "Implementing lean manufacturing with cellular layout: a case study." International Journal of Advanced Manufacturing Technology 42(7-8): 772-779.
[11] S. Vinodh, K. R. Arvind and M. Somanaathan, (2011), "Tools and techniques for enabling sustainability through lean initiatives." Clean Technologies and Environmental Policy 13(3): 469-479.
[12] D. Seth, N. Seth and D. Goel, (2008). "Application of value stream mapping (VSM) for minimization of wastes in the processing side of supply chain of cottonseed oil industry in Indian context." Journal of Manufacturing Technology Management 19(4): 529-550.
[13] S. Kalpakjian and S. Schmid (2006), "Manufacturing engineering and technology", 5th edition, Prentice Hall: 1227-1228.
[14] J. Allen, C. Robinson, and D. Steward (2001), "Lean Manufacturing, a Plant Floor Guide", Total Systems Development, Inc.: 360-373.
[15] S. Aft Lawrence (1992), "Second Edition, Productivity measurement and improvement", Prentice Hall Inc: 9-20.