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A SIMULATION-BASED APPROACH FOR LEAN MANUFACTURING TOOLS IMPLEMENTATION: A REVIEW

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ABSTRACT

The objectives of this study are to ascertain the factors that elevate the effectiveness of Lean Manufacturing (LM) application and examine the present-day versions of LM tools simulation. This investigation embarks on a re-evaluation of the existing procedures for the application of LM in the production sector. Three factors that determine the effectiveness of LM implementation in an organization were identified. Currently available LM tools simulations are perceived to be wanting in user-friendliness and saddled with inadequate communication between modeller and client regarding progression from the theoretical model to the process engineering stage. The outcomes derived from this study were arrived at through multi score that includes Elsevier, Springer, Google Scholar, Research Gate and Institute of Electrical and Electronics Engineers (IEEE). Enhancement of the recommended tools will pave the way for better decision-making among LM professionals in the manufacturing domain.

Keywords: lean manufacturing, lean tools, lean simulation.

INTRODUCTION

Malaysia is in the process of working towards an economy that is highly competitive, vibrant, vigorous and durable by the year 2020 [1]. The 1980's witnessed the manufacturing quarter significantly elevate the economic growth by more than 8% for each year. The economy progressed from being overly-dependent on commodities to being a producer of quality manufactured goods for the export market [2]. This accomplishment can be traced to the innovativeness of manufacturing entities in their efforts to overcome obstacles hampering the efficient performance of a production scheme [3].

Kumar [4] and Sayem [5] opined that the major concerns of present-day manufacturers are increased productivity, quick distribution of goods and the generation of high-quality products at acceptable prices. Costa et al. [6] claim that the best route to higher returns is the generation of a wide range of goods in small lots. However, it ought to be borne in mind that alterations to procedures related to productivity within a manufacturing unit or at the company echelon goes hand in hand with costing. The profit margins achieved by a business entity or a particular corporation are directly linked to its capacity to realize a lead over its rivals in terms of productivity [7].

This research is arranged in the following order: (a) an outline on the Lean Manufacturing (LM) concept (b) the implementation of LM tools (c) an introduction to LM simulation and (d) an account of present-day LM simulation researchers. This investigation wraps up with recommendations for elevating the effectiveness of LM instruments application.

LEAN MANUFACTURING (LM) CONCEPT

The dilemmas dogging current manufacturers include waste, restrictions related to space, elevated changeover periods and increased production overheads. Mahfouz *et al*.,[8] asserted that LM has the potential to lessen, or even eradicate the drawbacks posed by these obstacles. LM is based on the thinking that the production system can be enhanced through the removal of non-value added work or waste [9]. Waste refers to actions that deplete resources without generating any value for the manufactured goods or facilities [10]. LM lessens the processing time while ensuring quick delivery of a wide range of favourably priced premium goods [11].

Presently, other than the manufacturing sector, LM is also applied in the healthcare [12], construction [13] and pharmaceutical domains [14]. Rathje *et al*., and Wong *et al*. [15, 16] stated that 40% of corporations were unsuccessful during their initial endeavour to implement LM. Wahab *et al*., (2013) [17], Shah and ward (2003) [18], Achanga *et al*., (2006) [19], Hedelind (2011) [20], and Kovatch *et al*., (2011) [24] opined that the main obstacles to successful LM implementation include a deficiency in information and comprehension of LM, a work setting that is devoid of lean culture, and poor decision making by those in authority.

These findings led to the recommendation of a theoretical model for elevating the efficiency of LM implementation. As exhibited in Figure-1., the successful implementation of LM necessitates the involvement of three essential ingredients. These are (a) the application of lean culture in the work setting (b) waste recognition and (c) the application of LM instruments to raise the performance level of the manufacturing scheme.

The key ingredient for effective LM implementation is the application of lean culture in the work setting. The emphasis of lean culture is mainly on the interaction among employees, administrators and suppliers in industrial units [21, 22]. This stage is represented by two groupings. One is the primary team

comprising managers, engineers and human resources, while the other is the support team consisting of technicians, operators, drivers, clerks and cleaners [23]. The fundamental concern here is the alteration in conduct within the work setting. This includes a raised level of dedication among those in authority, enhanced interaction between the primary and support teams [24], being grateful and considerate towards attempts to bolster the team during problem-solving situations [25] and making available accurate reports on all issues [24].

Figure-1. Theoretical model of Lean Manufacturing

The successful implementation of lean culture through team effort clears the way for the next stage. This stage focuses on the recognition of waste in corporations. Seven frequently occurring waste circumstances were identified through the utilization of the LM concept. These include [26 - 28];

- **Overproduction:** Generating more than the requirement of clients (ill-timed production). Linked to 'overproduction' is 'inventory'. This waste refers to the build-up of raw materials at ongoing work sites.
- **Waiting:** Delayed receipt of materials, components, machines, and instruments etc. which lead to a disruption in the chain of production.
- **Unwarranted motion:** Movements that do not contribute to the enhancement of the quality of the product. These include substandard workflow, inferior layout, unsatisfactory housekeeping and unreliable or unrecorded work procedures.
- **Transportation:** The transference of any component or material that does not straightforwardly improve the quality of the product.
- **Over-processing:** This issue embraces reworking, deburring and checking.
- **Defect:** Production flaws and incompetent service.

Subsequent to the recognition of waste, LM tools are implemented to elevate productivity [28] through the lowering of expenditure, enhancing quality, lessening flaws [29], trimming down lead times [27] and ensuring prompt delivery of products [30]. The fourteen lean instruments available through the utilization of LM are Value Stream Mapping (VSM), Talk-Time, Kaizen, 5S, Jidoka, SMED, Poka-Yoke, Five-why, Standard work, Total Productive Maintenance (TPM), Cellular Manufacturing (CM), Heijunka, Just-In-Time (JIT) and Kanban (Peter, 2009) [31]. Table-1 exhibits several favourable outcomes resulting from the utilization of LM tools.

LEAN MANUFACTURING TOOLS SIMULATION

Simulation is employed as an instrument for elevating the efficiency of LM by imitating the manufacturing process without interrupting the chain of production. This process works to provide a better comprehension of the system [43] and is frequently utilized for assessing innovative planning schemes, evaluating contemporary production procedures and easing the way towards actual implementation of the manufacturing process [44 - 47]. The most significant attribute of simulation is its methodology in the context of costing as it allows for performance evaluation without actual implementation or disruptions to the chain of production.

Many simulation techniques have been developed for the implementation of lean manufacturing tools. These include assembly electrical plug [48], hospital game [49], Lego game [50] and 5S game [51]. These techniques can be categorized as off-line simulation as they are more inclined towards proactive implementation or well-established procedures. On the other hand, on-line simulation which is an amalgamation of simulation software and computer has developed into the method of choice due to its effectiveness in designing, forecasting and implementing the system [47 - 51]. Table-2 portrays recent studies and outcomes related to the utilization of LM tools in an industrial setting.

Nonetheless, present-day LM tools simulation techniques are not easy to apply and are hampered by a lack of communication between modeller and customer regarding information on progression from the theoretical model to the process engineering phase [62, 63]. A further setback linked to these techniques is their inclination towards static simulation [64] instead of dynamic simulation. Alzraiee *et al* (2013) [65] forwarded that the development of on-line simulation is confined to the domain of specialists.

Table-1. Implementation of LM tools in industrial settings curtail reduction.

Researcher	Field of research	Improvement	LM Tool
Ibrahim M.A et al., (2015) [32]	Textile Industries	Enhanced preparation efficiency of mould from 47.63 to 10 min (79%)	SMED
Mulla et al., (2014) [33]	Pumps Manufacturing industry	Raised the Overall Efficiency Equipment (OEE) by 5.32% Improved time delivery by 12%	
Sayem et al., (2014) [5]	Furniture Industries	Lowered the changeover time by 65.28%	
Costa et al., (2013) [6]	Punching machine	Lowered the setup time by 64% Lessened work in progress by 50% Curtailed operator travel distance during internal setup by 99% Benefits of €7,315.38 per year.	
Singh et al., (2013) [34]	Machine Shop	Eradicated un-planned breaks Halted the occurrence of breakdowns Elevated OEE by 16%	TPM + 5S
Kurunesh and Thatappa (2013) [35]	Mining industry	Decreased lead time from 90 to 50 days. Eased non-value-added from 51% to 48%.	VSM + Kaizen + Heijunka
Naufal et al., (2012) [36]	Automotive Industry	Lessened lead time by 40% Trimmed down progress inventory by 23%-29% Optimized the finished goods area by 4%	Kanban
Bhat and Shivakumar (2011) [37]	Hydraulic Industry	Lowered the lead time by 88% Minimized the processing time by 23% Decreased the required workforce by 40%	VSM + Kanban
Pan et al., (2010) [38]	SME industry in India.	Cut down total inventory by 83% Lessened cycle time by 4% Decreased the required workforce by 17% Lowered the lead time by 84%	VSM
Mujtaba et al., (2010) [39]	Telecom Company Ericson AB.	Eased the overall time expended on software expansion by 38%	
Yang and Zhang (2008) [40]	China Air Conditioner Manufacturer	Raised productivity by 50% Trimmed down the cycle time by 39.62 minutes	
Carr (2005) [41]	Rubber Manufacturing Plant	Cut down the lead time by 66% Enhanced the throughput by 20%	
Buggy and Nelson, (2005) [12]	Healthcare	Lessened the patient walking distance by 73% Lessened the staff walking distance by 30% Achieved general cost avoidance of $400K. Raised capacity gain by $2.5M in charge.	JIT + 5S + Poka Yoke
Singh et al. (2011) [42]	Metal Machinery	Limited the production cycle order to 9 days from 21 days (57%)	VSM + Kanban + Work Standardization
Abdulmalek and Rajgopal, (2007) [28]	Steel Industry	Curbed the Lead Time from 48 days to 15 days. Decreased the inventory range from 96 coils to 10 coils (90%)	Total Productive Maintenance (TPM)

CONCLUSIONS AND FUTURE WORK

This investigation recognized three essential factors for the successful implementation of LM tools. These are (a) the identification of waste in the production chain (b) the application of lean tools in the manufacturing process and (c) the development of lean simulation. These factors come together to elevate the efficiency of lean implementation.

Lean Tools Simulation (LeTS-2015) has been recommended for boosting usage and improving LP comprehension. Comprising three lean tools, LeTS-2015 can be utilized for assessing the production scheme and raising the capacity for good decision-making on the part of lean practitioners.

The main interface of LeTS-2015 is illustrated in Figure-2. Three key LM tools (Kanban, Cellular Manufacturing and Single Minute of Exchange Die) were opted for in this application. These tools were chosen based on a survey conducted by Kovach *et al*., (2011) [24].

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Table-2. Implementation of simulation lean manufacturing tools in an industrial setting.

Researcher	Software	Finding
Visakh and Aravind (2014) [52]	ARENA Simulation, MINITAB statistical software, Taguchi method, ANOVA	Recognizes the Design of Experiment (DOE). Taguchi`s design method is appropriate for optimizing the manufacturing parameter (inter-arrival time, layout and shift).
Senthiiland and Shirrushti (2014) [53]	ProModel (Dynamisis)	Simulates the production compressor in the context of movement, waiting time, manpower, rework, and space. Raised productivity from four to six models per day. Decreased the number of operators from 3 to 2 individuals
Anbumalar et al., (2014) [54]	ARENA Simulation	Recognized the appropriate layout (oval-shape, linear-shape, l-shape, u-shape and s-shape). Straight is deemed the apt layout for curtailing manufacturing expenditure.
Mohamad and Ito, (2013a) [55]	ARENA Simulation	Expands the Lean Manufacturing Training System to elevate the efficiency of lean tools implementation. Emphasizes on SMED lean tool.
Mohamad et al., (2013b) [56]	ARENA Simulation	Appraises the efficiency of Lean Tools (SMED and Cellular Manufacturing) in coolant hose production Imparts confirmation on the viability of implementation
Ruikar and Telsang, (2013) [57]	Minitab statistical software	Just-In-Time with Simulation is appropriate for recognizing and overcoming stumbling blocks to successful implementation
Lemessi et al., (2012) [58]	SLX Software (Wolverine Software Corporation.)	Simulation can be utilized for recognizing bottlenecks and for enhancing authenticity
Mohamad. E., and T. Ito, (2012) [59]	Arena Simulation	Recommends SMED training through the utilization of simulation Alters conventional training procedures through the usage of slideshows, brochures etc.
Al-Khafiji and Al-Rufaifa (2012) [60]	Arena Simulation	Simulates VSM to facilitate better production and demand processing by decreasing line intersections with optimal utilization of accessible amenities Reduces Work In Progress (WIP) by 52% in relation to inventory and procedure
Ito, T. and E. Mohamad. (2010) [61]	ARENA Simulation	Gauges the usefulness of material management in the context of line balancing Decreases total time for the generation of 600 manufactured goods per week from 256.49 to 208.06 hours Trims the lead time from 5 days 7.9 hours to 4 days 6.8 hours

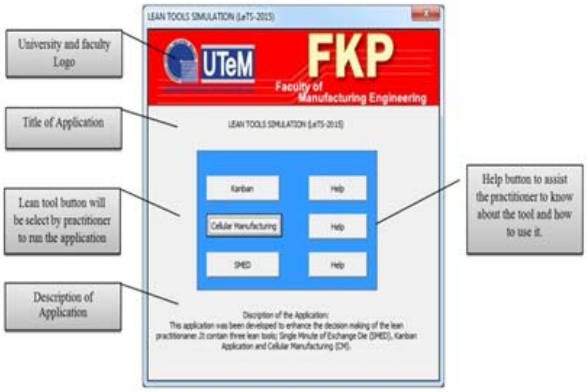

Figure-2. LeTS-2015 interface.

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