Research Article

Effect of Lean Practices on Lead Time Reduction

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Abstract: This article presents a study on the effect of Lean practices on lead time reduction. In this study, we have proposed the consideration of human, technical and environmental factors in the study of the impact of production scheduling and SMED on manufacturing lead time. Based on the fact that scheduling and SMED go well beyond a calculation function. From our point of view, it is preferable to broaden the field of study of this impact by going beyond the fields of mathematics, operational research and artificial intelligence. In this study, we propose to start from the idea that there are other factors that can influence the expected results, namely human, technical and environmental factors. To achieve this, we went through a literature review and then tried to validate our hypotheses through a quantitative study.

Keywords: Lean, Production Scheduling, SMED, Lead Time, Impact, Morocco.

1. Introduction

Most manufacturers would agree that lead time can be an effective competitive weapon as customers become less patient and less willing to wait for delivery of what they order. The reduction of lead time is a major factor of several industrial customers which shows present industrial scenario. A good Lean practices implemented such as production scheduling and SMED produces high quality product at the speed of customer demand with minimum waste (Peter Ward & Honggeng Zhou, 2006). Many companies with an aim of increasing efficiency and effectiveness (Womack and all., 1990; Snee, 2010) have adopted lean practices. This means continuous improvement in quality services and products, waste and cost reduction, customer satisfaction and job satisfaction.

But after the implementation of Lean practices, the majority of companies find a significant discrepancy between the results calculated theoretically and the results found in the field. We can explain this discrepancy by the fact that there are factors not taken into consideration beforehand that impact the expected results, namely human, technical and environmental factors.

That is why, in our investigation, we have admitted that the problem of Lean Manufacturing requires a study from a sociotechnical point of view, focusing on the effect of the human factor in the adoption of Lean Manufacturing. Also, we have taken into consideration the internal environmental factor in our investigation. We can say that the study of the effect of Lean practices (production scheduling and SMED) on the manufacturing lead time by taking into consideration these factors still remains a blank space and raises several questions.

It is in this context that our research work takes place. The aim is to study the impact of the two methods of Lean Manufacturing, namely production scheduling and SMED, on the manufacturing lead time by focusing the study on the three factors mentioned above. So our research problem: What is the impact of scheduling and SMED on lead time?

The rest of the article is organized as follows. The following section reviews the literature related to Lean Manufacturing, SMED, production scheduling and lead time. In the second part, we will present the data collected, the sample chosen and then the results obtained.

2. Literature Review

2.1 Lean Manufacturing

Lean manufacturing is a production philosophy that strives to eliminate waste in all activities within an organization (Kraebber, 2000). The elimination of waste allows a product to flow through the manufacturing process in smaller quantities than that required by the batch-andqueue process.

Following the postulate of Heizer and Render and Slack et al, although the definitions of Lean Manufacturing have continued to broaden and evolve as the concept of Lean Manufacturing has become more widely accepted worldwide (Goyal and Deshmukh, 1992), a consensus has been reached on its fundamental objective: to improve operational performance through the elimination of waste (Heizer and Render, 2011; Slack et al., 2010). The following are examples of the definition of Lean manufacturing drawn from a number of well-known studies:

- LM is a philosophy, an approach and an integrated management system that synergistically aims at improving operational performance in a production system (Bartezzaghi et Turco, 1989).
- LM is a holistic approach to continuous improvement based on the notion of eliminating non-value added activities in a production system (Sakakibara et al., 1997).
- LM is a manufacturing philosophy aimed at reducing delivery times and operating costs, improving employee performance, skills and satisfaction levels (Creese, 2000).

In accordance with the definitions of previous studies and the orientation of our research, this study defines Lean manufacturing as a sociotechnical approach which encompasses a wide variety of management practices that work synergistically to reduce waste.

The sociotechnical approach proposes that the design of the work should take equal account of the human and technical contexts in which the work is to be undertaken. As Mumford says, "the goal of sociotechnical design has always been the joint optimization of social and technical systems" (Mumford, 2006). The sociotechnical system has brought a more balanced perspective to Lean Manufacturing research, which has led to a greater emphasis on the social pillar of Lean in more recent Lean Manufacturing research.

2.2 Production Scheduling

Scheduling is a branch of operations research and production management that aims to improve a company's efficiency in terms of production costs and delivery times. Scheduling the operation of an industrial production system consists in managing the allocation of resources over time, while optimizing a set of criteria (Rodammer et al., 1987). It also means scheduling the execution of an achievement by allocating resources to tasks and setting their execution dates (Carlier et al, 1988).

There are three main categories of scheduling constraints: temporal, technological and resource constraints. The first type concerns the imposed manufacturing deadlines. The second type corresponds to the technological constraints, generally described in the product manufacturing ranges. The last type of constraints concerns the limitation of the quantity of resources of each type. A resource is a technical or human means used to perform a task.

The objectives concerning a scheduling are varied (Esquirol et Lopez, 1999):

- Time: Examples include minimization of total execution time, average completion time, total setup times or delays in delivery dates.
- Resources: Maximizing the load of a resource or minimizing the number of resources needed to complete a set of tasks are objectives of this type.
- Cost: these objectives are generally to minimize the costs of start-up, production, storage, transport, etc,

2.3 SMED

SMED is the abbreviation for Single Minute Exchange of Die, which can be translated as "tool change in less than 10 minutes" or "quick tool change".

Maynard and Zandin (2001) have defined the process of change of series as the transformation of a model manufacturing system from one product to another, including the current work stoppage in preparation for the next process. In this context, the changeover time can be defined as the time that elapses from production stoppage A to the next fault-free product B.

Van Goubergen and Van Landeghem (2002) define changeover time as the time when the final product (product A) leaves the machine until the next product (product B), which has been produced with good quality.

The need to reduce changeover time is not new. In fact, the time elapsed between the production of the last product of a series and the first product of a new series meeting all quality requirements has always been considered a waste of production.

Reducing changeover time has many benefits, such as increasing the capacity of the manufacturing system, reducing lead times, reducing inventory levels and lowering production costs.

2.4 Lead Time

The lead time has been recognized as an important measure of operational performance. Tersine stated that the manufacturing delay could take on different meanings depending on the range of activities included in the interpretation (Tersine, 1994). Manufacturing time can refer to flow time (Feld, 2001), processing time (White & Prybutok, 2001; Zelbst et al., 2010) and cycle time (Olsen, 2004; Tersine, 1994).Christiansen et al. evaluated delivery times in three different categories (Christiansen et al., 2003), i.e. purchase time, manufacturing time and delivery time (delivery time to customers).The time to purchase or supply has been defined as the time elapsed between placing an order with the supplier and receiving the items purchased from the supplier (Jayaram & Vickery, 1998). The manufacturing lead time is the time that a particular item spends on the production line from its first entry to completion (Singh et al., 2010).In other words, it is the total manufacturing time necessary to carry out all the necessary operations exclusively in the factory, from the beginning of the first to the end (Tersine, 1994). The delivery time is the time between when the finished products are picked up from the manufacturer and when they are delivered to customers (Wu, 2003).

In this study we will focus on the manufacturing lead time. Cheng and Podolsky divided this delay into five elements, namely setup time, processing time, waiting time, transfer time and queue time (Cheng and Podolsky, 1993). Likewise, Russell and Taylor considered the manufacturing time to be four elements. These are setup time, processing time, transfer time and waiting time (Russell and Taylor, 2008).All components of the delivery time are defined as follows:

- Setup Time: The time required to prepare equipment, materials, and workstations for an operation. It can be reduced by performing most of the outside installation activities that can be done while the equipment is in operation.
- Processing time: the time required to perform productive / value-added operations. This can be shortened by reducing the number of items processed and increasing the efficiency of equipment and operators.
- Waiting time: the waiting time for a part to be moved to the next operation. Proper planning of materials, equipment and operators can reduce it.
- Transfer time: the time required to transport from one workstation to another. Reduction in travel time is possible if machines are located closer to each other, if movement is simplified, routing is customized, and if the layout can be easily reconfigured.

This study takes into consideration the manufacturing time in terms of setup time, processing time, transfer time and waiting time.

2.5 Effect of Lean Manufacturing on Lead Time

Time-based competition was on the horizon (Koufteros et al., 1998). Shorter lead times have become a major source of competitive advantage for manufacturers in all sectors. A company's ability to manage production time can determine a company's success in its competition. This ability can help a company achieve higher profits, increase market share, improve customer satisfaction, and reduce risk (Koufteros et al., 1998).Because of the importance of time performance, researchers such as Nahm et al. and Koufteros et al. have put forward the idea of a time-based manufacturing system aimed at reducing the time required, not only in production processes but also in delivery to customers (Nahm et al., 2006; Koufteros et al., 1998).

Manufacturing companies are trying to reduce their production lead times. The role of Lean Manufacturing is also very important because it is a systematic approach to achieve the shortest cycle time and lead time, as well as a process management philosophy (Heizer& Render, 2008)."Lean LM aims to produce products or services using minimum levels of everything, such as minimum capital investment, minimum human effort and minimum waste". The key element of the Lean strategy is to develop a learning system that has the ability to identify and distinguish between value-added activities and wastes.

Davis and Heineke also highlighted the experience of several companies in eliminating waste through value-added production; reducing average inventory by approximately 1.5 million euros; reducing processing time by 50% to 70%; reducing preparation time by 50% without major investment in plant, machinery and equipment; increasing productivity by 20% to 50% (Davis and Heineke, 2005).

There are a number of LM practices that could help reduce delivery times. Anand and Kodali have concluded that delivery times can be reduced by standardizing production levels, including balancing workloads and standardizing processes (Anand and Kodali, 2009).

Producing in small quantities also favours a shorter delivery time, rather than producing in large quantities (Bartezzaghi & Turco, 1989). More importantly, the reduction in preparation time due to rapid set-up also significantly shortens lead times (Callen et al., 2000). Other practices, such as resource flexibility, the use of cellular layouts, the printing system, TPM, quality control, and supplier networks, contribute to the reduction in lead times. This view has been supported by several previous studies, such as Callen et al (2000), Fullerton and McWatters (2002), Chong et al (2001), Shah and Ward (2003), and Matsui (2007), which have confirmed the positive relationship between LM and delivery time.

3. Research Framework and Data Analysis

3.1 Population and Sample Selection

This survey started on August 08, 2020. The data was collected by questionnaire.

- The sector of activity: the study targets the industrial sector in Morocco
- Size: the study targets large companies.
- The field of study: national and international industrial companies established in Morocco.
- Sample: our sample consists of 65 companies.

The companies surveyed are divided into sub-sectors of activity in the table below:

Table 1. The distribution of respondent firms by industry sub-sectors

Subsector of activity	Total number of companies	%
Automotive	42	64,61%
Aeronautics	15	23,07%
Agribusiness	8	12,30%

Table 2. Profile of the companies surveyed

Size of the company		
Demography	**Number**	**%**
Less than 1 000 000 MAD	12	18,46%
1 000 000 and more	53	81,53%
Number of employees		
Demography	**Number**	**%**
Less than 300 employees	10	15,38%
More than 300	55	84,61%

3.2 Testing the Validity and Reliability of Variables

In this study we based ourselves on the paradigm of (Churchill, 1979), which proposes to eliminate the least representative, ambiguous and redundant items of the concept, in order to have a perfect measure of the studied phenomenon, and therefore a validity of content. Thus, we conducted a principal component factor analysis (ACP). The tables below summarize the results obtained from the ACP.

Table 3. ACP test results

Explanatory variables: Scheduling	**Items**	**Test KMO**	**Test Barlett**	**Restored Variance**	**Alpha Cronbach**
Human Factor	9	0,779	000	73,96%	0,83
Technical Factor	4	0,762	000	69,23%	0,77
Environmental Factor	5	0,747	000	71,08%	0,74

Explanatory variables: SMED	**Items**	**Test KMO**	**Test Barlett**	**Restored Variance**	**Alpha Cronbach**
Human Factor	9	0,782	000	77,63%	0,86
Technical Factor	5	0,713	000	76,23%	0,76
Environmental Factor	5	0,661	000	70,36%	0,70

Variable explained	**Items**	**Test KMO**	**Test Barlett**	**Restored Variance**	**Alpha Cronbach**
Lead Time	4	0,723	000	61,33%	0,80

The calculation of the Cronbach's Alpha for the variables "Human Factors", "Technical Factors" and "Environmental Factors" gives satisfactory results (> 0.70) for the assessment of reliability. These results underline the internal coherence between the items retained for the variables in question.

The ACP carried out allows the extraction of a single component that allows the restitution of the total variance greater than 0.6, which is well represented. Thus, each item contributes in a formal way to the selected component.

3.3 Research Model Evaluation

For the evaluation of our research model, we opted for the structural equation analysis method using SmartPLS 3 software.

We evaluated our research model based on these two criteria: internal consistency reliability and discriminant validity.

3.3.1 Reliable Internal Consistency

The reliability of internal consistency is verified by two measures: Cronbach's Alpha and composite reliability (Hair et al., 2017). The table below presents the values obtained for each variable:

Table 4. Values obtained from Cronbach's Alpha and composite reliability values

Variables	Alpha Cronbach	Composite reliability
Scheduling	0,86	0,80
SMED	0,84	0,79
Lead Time	0,81	0,87

We notice that all values are higher than 0.7, we can deduce that our model so far is reliable.

3.3.2 Discriminatory Validity

Discriminant validity represents the extent to which the measures of one construct differ from the measures of another construct in the model (Fernandes, 2012) [31].

The discriminant validity of our research model is assured. In the table below, we have the inter-item saturation coefficients.

The objective of this analysis is to specify the existing relationships between the dimensions of the search model. The table below shows the relationship between the explanatory variables and the variable to be explained.

Table 5. Table of saturation coefficients between items

Variables	Lead Time	Scheduling	SMED
Lead Time	0,785		
Scheduling	0,827	0,891	
SMED	0,846	0,768	0,771

3.4 Analysis of the Direct Relationships between the Dimensions of the Research Model

The objective of this analysis is to specify the existing relationships between the dimensions of the search model. The table below shows the relationship between the explanatory variables and the variable to be explained.

Table 6. The regression coefficients of the selected model: dependent variable "lead time".

Scheduling -> Lead Time	
R-deuxajusté	**Model equation**
0,672	**DF =** 0,520 AVAI + 0,650 EXPE + 0,617 TRAI + 0,418 MOTI+ 0,642 COMP + 0,519 COMM+ 0,127 VERS + 0,429 MULM + 0,678 TOOL +0,119 MLOC+ 0,632 COMS + 0,210 SPEC -0,0288 DIFF - 0,0528

SMED -> Lead Time	
R-deuxajusté	**Model equation**
0,618	**DF =** 0,651 DEXT + 0,589 EXPE + 0,493 VERS + 0,379 AVAI + 0,562 COMP + 0,462 TRAIN + 0,375 MULM + 0,527 TOOL + 0,528 MLOC + 0,493 COMS - 0,050 DIFF - 0,0324

Competence	**COMP**	Communication	**COMM**
Availability	**AVAI**	Dexterity	**DEXT**
Versatility	**VERS**	Machine location	**MLOC**
Experience	**EXPE**	Tools	**TOOL**
Training	**TRAIN**	Multifonctional Machine	**MULM**
Motivation	**MOTI**	Company siza	**COMS**
Differenciation	**DIFF**	Specialization	**SPEC**

For the first "Scheduling and lead time" relationship, regression analysis of the lead time variable allows the extraction of a single model that explains 67,20% of the total variance.

For the second "SMED and lead time" relationship, regression analysis of the lead time variable also allows the extraction of a single model that explains 61,80% of the total variance.

It can be seen that both explanatory variables contribute significantly to the total variation in the lead time variable.

This test allows the researcher to confirm or disprove each hypothesis, and to understand the strength of the relationship between dependent and independent variables.

3.5 Testing Research Hypotheses

The research hypotheses formulated:

H1: Production scheduling can have a positive impact on lead time.
H2: SMED can have a positive impact on the manufacturing lead time.

This test allows the researcher to confirm or disprove each hypothesis, and to understand the strength of the relationship between dependent and independent variables.

For this purpose, we used a procedure called "Bootstrapping", which allows us to sample a large number of times the initial sample, which was actually taken from the population. This re-sampling method allowed us to obtain student t-values, which we used to validate or reject our hypotheses (Chin, 1998) [32]. The table below presents the validation status of our research hypotheses:

Table 7. State of validation of research hypotheses

Hypotheses	O	M	STDEV	t value	p value	Status
Scheduling -> Lead Time	0,826	0,842	0,118	8,264	0,000	**V**
SMED -> Lead Time	0,725	0,751	0,121	7,859	0,000	**V**

According to the results, the two research hypotheses were validated based on our sample.

4. Conclusions

This study has shown the effect of Lean practices, namely production scheduling and SMED, on manufacturing lead time.

The conceptual model was developed based on the fact that there are human, technical and environmental factors that can hinder scheduling and SMED has achieved the expected results if they are not taken into account beforehand.

Following a field study of 65 industrial companies in Morocco, we conducted an analysis of model validity and reliability and then studied the descriptive assumptions of the research model through multiple regression analysis.

This analysis allowed us to achieve the following results:

- Production scheduling has a positive effect on lead time.
- SMED has a positive effect on lead time.

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