





# PRODUCTION ENGINEERING ARCHIVES

ISSN 2353-5156 (print)  
ISSN 2353-7779 (online)

Exist since 4<sup>th</sup> quarter 2013  
Available online at <https://pea-journal.eu>

## The use of Lean Six-Sigma tools in the improvement of a manufacturing company – case study

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### Article history

Received 15.01.2020

Accepted 20.02.2020

Available online 31.03.2020

### Keywords

Lean-Six Sigma

Handicraft

Manufacturing

### Abstract

Handicraft production is usually chaotic and difficult to monitor, since its products and manufacturing processes are complex. As all the manufacturing steps rely on varied skill levels of the workers, the situation is even more stochastic. There are several common problems, such as inappropriate production method, line unbalance, excessive stock, lack of production planning and control phases, etc. They stem from the lack of suitable operation model, redundant workforce usage, and insufficient internal training activities, which lead to the waste of human resources. In this paper, a roadmap to improve the operational efficiency of handicraft manufacturing is suggested, using Lean-Six Sigma methodology and tools. A case study is conducted in a Vietnamese firm to show the validity of the approach.

DOI: 10.30657/pea.2020.26.07

JEL: L23, M11

## 1. Introduction

Since Toyota and Motorola invented Lean manufacturing and Six Sigma methodologies respectively, the manufacturing industries around the world have witnessed an ever-changing tide in operational efficiency improvement movement (Womack et al., 1992; Schroeder et al., 2008). With the Lean philosophy of cutting wastes in activities, and the Six Sigma philosophy of focusing on quality within an acceptable tolerance, their utilizations are reasonably linked with each other, aiming at higher competitiveness for enterprises, and to be known as Lean – Six Sigma. Common benefits can be listed as reliable supplier relationship, low inventory volume, shorter lead-time, high utilization of human resource, higher quality, less defect and systematic faults. Both separate applications of the two philosophies, or the twin as a whole, brought significant success for manufacturing companies in different fields, such as automotive, assembly line, electronics, clinics, laboratory, logistics, etc. (Matt and Rauch, 2013; Arslankaya and Atay, 2015; Nguyen Thi et al., 2016; Zhang et al., 2016; Costa et al., 2018; Krishna Priya, Jayakumar and Suresh Kumar, 2019; Schmidt, 2019; Teplická et al., 2015).

Although Lean-Six Sigma improvement tools helped to gain tremendous triumph in many fields, the handicraft production has not gained any achievement so far due to many factors,

(Chaple et al., 2014) namely, this type of industry tends to concentrate in provincial towns far from industrial development typical for metropolitan areas (Anderson, 1982). Handicraft manufacturing requires large effort during seasonal work periods, but does not produce identical results, generates low income, and its growth is slow (Qadri, 2018). Due to the fact that handicraft products are varied in models, machine, technology and automation advancement will not contribute to higher productivity of this industry. However, because of this sector's importance in many developing countries and its major role in the culture, some pioneer researchers try to apply improvement tools in this area, and gained significant outcomes (Qadri, 2018) by reducing the operation costs and enhancing the quality, which is the core of this concept, by implementing the pursuit of perfection philosophy.

This research proposes a roadmap to utilize Lean-Six Sigma tools to improve the efficiency of handicraft manufacturing firm. A case study is conducted to show the initial success and a promising path for further development.

## 2. Literature review

A craft manufacturing is referred to as the handmade manufacturing approach, where not just cheap and traditional

products are made, but luxury ones, such as musical instruments and cars. In the 19th century, as well as nowadays, such massive companies like Aston Martin used to handcraft produce many of automotive parts like seats for elite and rich people (Singh et al., 2010). Sadly, the handcraft sector is declining due to mistreatment of the sector and artisans. Many researchers have addressed factors generating problems (Bhat, 2019) mainly lack of tourism, mechanical tools, and lack of financial support. There is research which can be applicable and scalable due to the scarcity of improvement projects. Not only because of the fact that little research has been conducted in this area, but the lack of a model for further benchmarking exercises, which makes the estimation of this industry harder, and the need of such research is high so as to determine the impact of the specified factors on the efficiency performance of the handcraft sector (Bhat, 2019).

In comparison to other manufacturing industries, handcraft manufacturing is more problematic to standardize (Titik Kristanti et al., 2019). Due to the fact that its value-added activities are labour dependent, the redundant or intensive usage of labour usually leads to the waste of operating cost, which is to be eliminated in Lean manufacturing. As a systematic method, Lean production is identified as a method of waste elimination (Chaple et al., 2014). With different tools and means, Lean is used to optimize the resources usage, and produce the best product with optimal price, which can save millions of dollars in manufacturing processes, which makes it an extremely significant philosophy for many industries. Lean and Six Sigma can be appropriate amalgamating methods to mitigate the shortcomings of mass handcraft production. As an effective tool handling dissimilarity and complexity in products' variants of structure, Six Sigma thinking helps to design and monitor sequence of production processes in handcraft manufacturing so that it becomes less troublesome. Moreover, time and motion study is in crucial role to maintain the calculated productivity for manufacturing, and reduce the variation in the skill-dependent tasks to stabilize the product quality.

In the world, only little research is conducted in this area, due to the scarcity of well-structured and well-organized handcraft manufacturing firms. Traditional ones are too small in scale to be scrutinized under the industrial perspective. A Moroccan firm is taken into consideration in the research of Chouiraf et al. (Chouiraf and Chafi, 2018a, 2018b). The researchers first identified the seven wastes system for handcraft production, then applied improvement tools to enhance the firm's operation. The most important financial questions regarding any process is how much the production costs taking into consideration the existence of direct and indirect costs. The main direct costs comprise raw materials and labour cost, while indirect costs are all the other incurred overhead costs, such as rent and bank interest. In order not to have a loss, both costs must be determined. Additionally, to maximize the artisans' earnings (AIACA n.d.), which is the main aim of such a social production firm, the cost must be reduced to the minimal level. The usual suggested method is to determine the variable/direct costs as the following: fabric cost (fabric con-

sumption, wastage, and price fluctuation in the market), dyeing cost (material cost, labour cost, and fabric wastage) (AIACA n.d.), all this direct cost will be added to the overhead cost for the rent, salaries of office staff, and marketing. The final cost of each item will be the total cost of the produced items.

The possibilities for cost cutting such as accumulating up stocks when the prices are low and store it, try to push tasks into workstations regardless of line balancing status, etc. However, these solutions are counter-productive according to Lean-Six Sigma philosophy. Taking into consideration that the prices vary according to purchased quantity, but the inventory fee as well, thus the Economic Order Quantity (EOQ) needs to be calculated for every stock type. In this stock-optimal sense, also the workplace can be well organized in 5S order.

### 3. Experimental

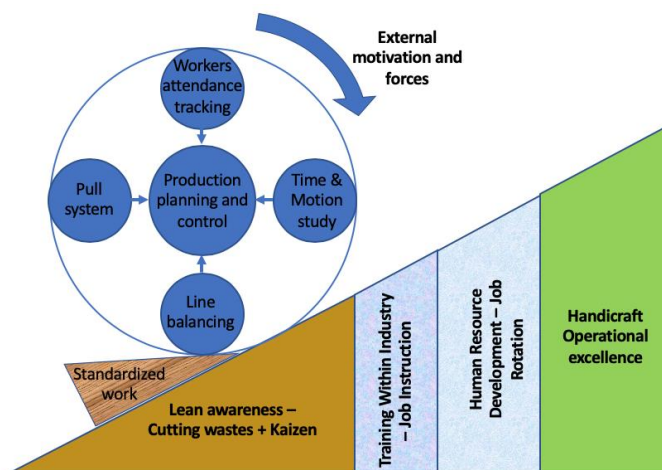
Since there is no sufficient research in handcraft manufacturing, the authors decided to consider the typical problems of some handcraft firms, and include some production firms that using labour's skills as well. They all have the same thing in common: the skill of the labour workforce determines the product quality, and such skills are hard to measure due to the abundant variation of product styles. Through literature review, some factors are listed as common problems and losses of a typical handcraft production system, as described in Table 1 below. For each problem, there is a corresponding Lean-Six Sigma improvement tool which is applicable.

According to the previous research, (Tran et al., 2016), handcraft manufacturing has a high interaction level between workers and working tools, thus, improvement tools such as Line balancing, Kanban, JIT, etc. – the ones with the emphasis on labour utilization – can be applied. A model for sustainable operation of handcraft production is suggested as presented in Fig. 1. It is integrated with the Lean-Six Sigma philosophy aiming to improve the operation efficiency. At the very base of the model, training for a thorough Lean awareness of reducing wastes and Kaizen is necessary, and needs to be maintained throughout the operation as a knowledge source. As the firm is motivated externally, production planning and control (PPC) play a vital role in the whole system in general, and MRP functions also as inventory level in particular. In order to gather necessary information for PPC to be effective, time & motion study needs to be recorded, and workers' attendance needs to be monitored. Other supporting philosophies to coordinate the production processes were pull system and line balancing, which serve ensuring the optimal utilization of labour work.

Since this operating model relied heavily on labour work, standardized work is a primary element, which prevents the operation from degrading. However, in order to achieve handcraft operational excellence, employing job instruction and job rotation are key to educate and train the personnel of the system, to conform with the work requirement and standard, acceptable processing time and motion, in order to stabilize output quality.

**Table 1.** Typical problems of handicraft manufacturing firms

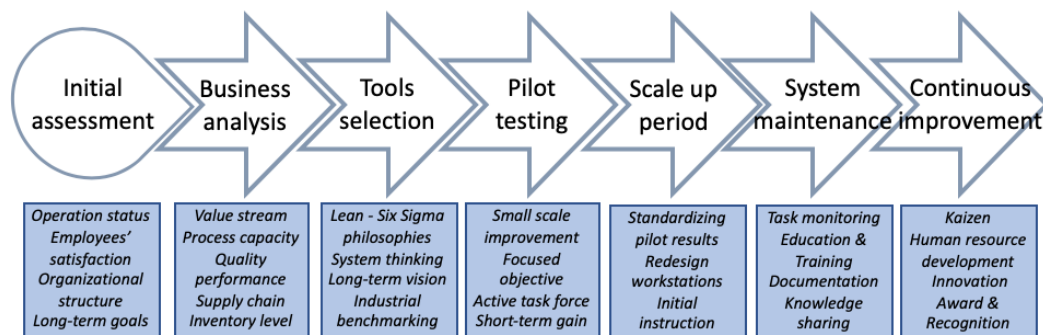
Problems and losses	References	Possible Lean – Six Sigma solution
Job production method, relies on the workers’ skills to finish on-off production.	(Ngoc Le, Do, and Nam 2012; Thi duc Nguyen, Tri Dang, and Thi Phuong Lan 2017)	Optimize work method, aim towards small batch flow.
Excessive and unequal process motion and time.	(Ngoc Le, Do, and Nam 2012; Thi duc Nguyen, Tri Dang, and Thi Phuong Lan 2017)	Time & Motion study, Standardized work
No MRP functionality. Thus, no inventory control, due to the uncertainty of production. Poor connection with suppliers.	(Thi duc Nguyen, Tri Dang, and Thi Phuong Lan 2017)	Deploy production planning and control function, in integration with Lean philosophies.
Uncontrolled work attendance and varied work skills, due to the small scale of enterprises. No sufficient internal training/coaching program.	(Nguyen Dang Minh and Toan 2014; Nguyen Dat Minh n.d.; Thi duc Nguyen, Tri Dang, and Thi Phuong Lan 2017)	Standardized work. Keep track of absenteeism. Job instruction. Job rotation.
Long lead time , work-in-process inventory, and over processing.	(Singh, Bhim, S. K. Garg, S. K. Sharma, and Chandandeep Grewal. 2010; Klimecka-Tatar, 2019)	Value stream mapping (VSM) can make significant reduction in lead time and inventory by more 80%, as well around 12% for processing time.
Effect of operational disruptions on the handicraft enterprise performance.	(De and Operacionales 2018)	By using kaizen activities to prevent disruption, the productivity, flexibility, and efficiency of the manufacturing system will be enhanced.
Low utilization of available resources.	(Bhat, Jahangir. 2019)	Optimal usage of resources, reducing the waste, for long term causes commitment and thus generate a brand loyalty.



**Fig. 1.** Sustainable handicraft operation model

The roadmap to implement the improvement project can be suggested as presented in Fig. 2. This roadmap shows six

steps tools implementation from the beginning of an improvement project until the manufacturing firm reaches the above-mentioned sustainable operation model. At first, an Initial assessment where a survey of the employees’ satisfaction and long-term goal must be determined. The Business analysis conducts a determination of the quality, performance and process capacity. After business analysis and initial assessment, the tool must be chosen according to the system thinking and the long-term vision through Lean-six sigma tools, which will be tested on a small scale in the next step named Pilot testing, where short-term results and gains can be evaluated, workstations and job instructions can be adjusted and redesigned, in order to obtain Scale up period, in which the change on a larger scale is implemented. In system maintenance, which can start one month after the scale up period has stabilized, the awareness can be forwarded to the employees by training and education. Kaizen and other human resource development is the final step, which leads to the main core of the Lean philosophy: Continuous improvement, by keeping innovation and development.



**Fig. 2.** Lean-Six sigma implementation roadmap for handicraft manufacturing

### 4. Results and discussion

The case study is conducted in Vietnam Pop-up Cards & Handicraft JSC, a company specialized in designing and manufacturing pop-up cards, operating production in thousands of product variants. In the scope of this paper, the authors will only mention the production aspect of this company, as an interesting subject of the improvement project. Several typical products of this firm are presented in Fig. 3 below, and, as each product variant has a different structure, and, therefore, requires different processes to produce, the production management is cumbersome and problematic to monitor.



Fig. 3. Typical product variants in the case study

The workforce encompasses 50 workers, and there are several major production processes such as cutting, assembling, gluing, stitching, packaging. Due to the deficiencies of production system, the firm suffered from some systematic problems which are as described in Table 2.

After three months of the improvement project, several Lean-Six Sigma tools were chosen and applied in pilot phase. The plant layout needs to be modified according to Fig. 4. Before change production type from job production one into a leaner one: small batch with Kanban, simulation test is conducted with Arena software. Three major production processes (i.e., assembling, gluing, stitching) are taken into consideration, involved three workers with different skill level at each of these processes. In job production, each worker conducts three tasks at one workstation, despite the fact that one worker is better at assembling, the other is good at gluing, etc. Since change into batch production, each worker is assigned into one workstation based on their skill level at which they are best of. The simulation for the new layout was run in Arena software for 3 weeks, with 10 types of most frequent product with different task time. After gaining the result of improvement, a new layout and production method is applied to practice. Other improvement tools implemented in this improvement project are listed in Table 3 below, in chronological order, with their details, and respective initial status and result.

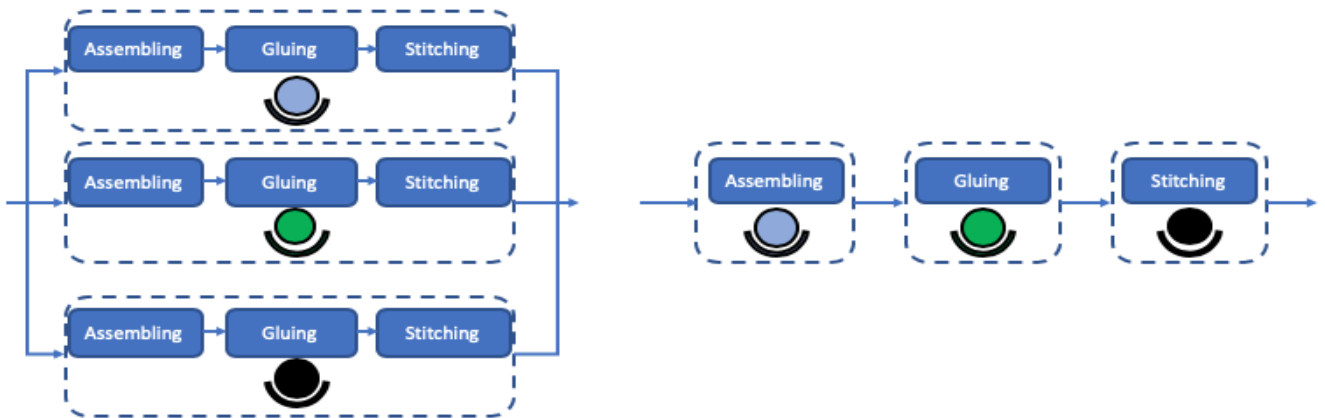


Fig. 4. Changing in production method and layout

Table 2. The situation before implementing the improvement project

	Input	Process	Output
<b>Problem</b>	Lack of optimal material order quantity. Loose connection with suppliers. Lack of inventory monitoring activities.	Ambiguous standard work instruction. Job production method, despite of large amount of order quantity. No training activities. Inefficient workstation layout. Intermittent communication between departments.	No tracking of loss ratio in output inventory. No record for defect and potential problems.
<b>Consequences</b>	Large and required space for inventory. Costly inventory with no tracking of usage status.	Uncontrolled WIP level. Higher ratio of defects. Under-utilized workers' competence.	Not any root cause is tracked.

**Table 3.** List of tools applied and corresponding results

No	Tools	Details	Initial statuses	results
1	EOQ calculation. Suppliers management.	Calculating the EOQ of each part by breaking down their price and inventory requirement. Develop a close connection with suppliers.	No optimum order quantity for each part. Unpredicted order lead time.	Reduce approx. 40% order lead-time of 3 suppliers. Deploy one order multi delivery policy. Inventory space reduced by 30%.
2	Inventory tracking + Safety stock	Use inventory card with procedure to record usage rate. Calculate the safety stock for each part.	No usage rate record. No safety stock level.	Reduce 25% of finished-part inventory, 20% of material inventory. Approx. 18 000 USD.
3	Changing production type	Changing from job production into small batch production with Kanban card.	Approx. 45.000 part/day. Total failure rate = 0.0647%	Simulation result: 50 000 part/day. Total failure rate 0.0254%. A practical result: Approx. 48 000 part/day. Total failure rate = 0.0275%. Process failure rate reduces 71% at peak.
4	Standardized work	Design standardized work instruction for each workstation based on the new plant layout.	No work description. Vague quality requirement.	Biggest defect quantity reduced by 70%.
5	Training within the industry – Job Instruction	Deploy Job Instruction method for team leaders, with the designed standardized work.	No training activities.	Team leaders have 15% time for training and coaching activities.
6	Time & Motion study	Observation for each process, and record temporal data. Assign time allowance for each task.	No record.	Time variation within 10% for workers in the same class.
7	Production planning	Elaborate concept of semi-automated production planning, based on time study and approximation of learning curve.	No reliable production planning.	MRP function formed. Simulation result: Planning has 97% of accuracy. A practical result: 93%.
8	Production control	Perform controlling with pull strategy, with Kanban card for small lot size.	No control activities within one day.	Control has 90% of efficiency, within one day frame.
9	Job rotation	Rotate workers among workstation.	No HR development activities.	More readiness in work.

## 5. Summary and conclusion

In this research, handicraft production and its complexity, chaotic characteristics were taken into consideration, and suitable Lean-Six Sigma tools were chosen to be applied for each problem of typical handicraft firms. Based on literature review and interview, an operating model for Vietnamese SMEs in this type of manufacturing was elaborated, which integrated improvement philosophy and tools. A roadmap for implementation is developed, and the case study conducted within the framework of an improvement project proved the efficiency of the suggested method. However, this study is still in lack of absenteeism, and dynamic approach of production controlling such as adaptive production sequence, flexible line balancing.

Other monitoring methods can be further deployed such as varied cycle time, optimal sequencing, which can be targeted at for future research.

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## 精益六西格玛工具在改善制造公司中的使用 - 案例研究

### 關鍵詞

精益六西格玛  
手工业  
制造业

### 摘要

由于手工艺品的产品和制造过程很复杂，因此手工艺品的生产通常很混乱且难以监控。由于所有制造步骤都依赖于工人的不同技能水平，因此情况变得更加随机。常见的问题有很多，例如生产方法不当，生产线不平衡，存货过多，缺乏生产计划和控制阶段等。这些问题是由于缺乏合适的运营模式，多余的劳动力使用以及内部培训活动不足，这导致人力资源的浪费。在本文中，提出了使用精益六西格玛方法和工具提高手工艺品制造运营效率的路线图。一家越南公司进行了案例研究，以证明该方法的有效性。