Application of Value Stream Mapping to Improve Financial Performance of a Production Floor: a Case Study

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Abstract

This paper is focused on application of value stream mapping in a production floor of a furniture industry with a view to enhance its performance. Analysis of cost is implicated with the value stream maps to secure economic justification. The data was collected from the production floor to develop the current state map from where the non-value added activities and other sources of wastes were investigated and areas of improvements were identified to minimize or eliminate them. Incorporating the improvements proposed, this paper suggests a future state map for the upholstery section as well as analysis and result obtained from the application of value stream mapping. The comparative analysis of current and future state map suggests that adapting the concept of Lean can repose momentous contribution in the industry by reducing production lead time by 66.67% while lessening the cost by 11.25%. This paper highlights the monetary impact of adaptation of value stream mapping by showing that incorporating Lean concept with the utilization of value stream mapping can help industries to provide high customer response with lower costs which is vital to enhance competitive performance in existent market situation.

Keywords
Lean manufacturing, Value steam mapping, Cycle time, Production cost, TAKT time.

1. Introduction

One of the ever-incrementing challenges that industries face today's world is to maintain good customer response along with minimization of cost, reduction of inventory and ensuring quality to survive in the competitive market in worldwide scale. To enhance organizational and competitive performance, diverse kinds of improvement techniques and methodologies are accommodated by organizations. Concept of Lean Manufacturing is one of the approaches that has been popular among manufacturing and construction facilities assisting to reach organizational goals. In 1990, Womack et al. popularized the philosophy of Lean thinking in the book named 'The machine that changed the world: The story of lean production' as an effective means of eliminating wastes. Lean is the most potent tool to maximize customer value though the elimination of wastes taking place in many forms at any place at any time in the organization (Kumar, 2016; Lacerda et al., 2016).

Value stream mapping (VSM) is one of the most exigent tools for adaptation and maintenance of Lean in any industry. It is a simple pencil and paper representation which provides with an ample view of production flow from upstream to downstream establishing a relationship between both information and material drift. VSM is a process mapping approach that uses dedicated icons to visualize the process clearly and identifies the areas of improvement by reduction or elimination of process wastes. The fundamentals to implement value stream mapping are to draw a current state map portraying the existing process, find possible changes and uplifts and develop action plan to reach a future state map incorporating the continuous improvement (Forno et al., 2014).

Most of the companies can't realize the monetary aspect of adopting Lean because conventional costing systems are not concerned with the aspects of Lean Manufacturing principles and independent of production time. As production cost primarily depends on the speed of product flow through the value stream, value stream mapping can be useful as an effective tool to bridge between operational and economic organizational views. (Ramadan et al., 2017). So, if value stream mapping can be integrated with cost calculation, the economic feasibility and financial impact of Lean adaption can be justified and thus diagnosis and sanction of Lean improvements can be carried out with more degree of confidence in the industry.

In this paper, value stream mapping tool followed by expense evaluation was utilized in a furniture industry in Bangladesh in upholstery section which is dedicated to provide furniture with foams, padding, spring etc. as required. Research regarding the application of value stream mapping in furniture industry is rare because furniture sector is not fully industrialized with specific production lines for respective product families in most cases yet especially in developing countries like Bangladesh.

This research was conducted based upon a real life case study conducted on a furniture industry which is in the process of industrialization getting out of the traditional carpentry works. The industry is currently struggling to survive in the middle class market due to high price resulting from high expense in the production. Besides, the industry has a long term vision to step into global market by exporting their product which further calls for necessity to enhance competitive performance. Hence, the company is motivated to implicate lean tool in the industry to achieve company goals more efficiently. Value stream mapping is a new tool for them which is not applied yet in this industry. In this research an approach was taken to initiate value stream mapping in upholstery section of a furniture industry to reduce lead time, wastes which in turn results in reduction of cost.

Though there exists enormous previous research on the utilization of value stream mapping in environments like manufacturing, healthcare, construction etc., traditional value stream mapping seldom takes costing system in account. There are few works that evaluate and justify cost and financial outcome of Lean and value stream mapping implication in production specifically furniture section. So this is the underlying motivation of this research to make a contribution to compensate for this gap.

The objective of this paper is to initiate the adaptation of Lean in a furniture industry by the application of value stream mapping following a cost based approach that will help the organization to trigger production that will manufacture high quality production with minimum wastages, better inventory control along with financial justification. To reach this objective, based on the selection of product family and collection of necessary data, current state map of the existing process was designed. Then this map was analyzed thoroughly to investigate the shortcomings and wastes and suggestions were proposed to overcome them. In light of the suggestions, the future state map was portrayed. The anticipated outcome from the proposed future state map was derived with the inclusion of limitations of this research and scope of future work.

2. Literature Review

VSM has been adopted by different industries, construction work and complex environments to maximize efficiency in the field of application. Some of the previous works in this field are discussed in brief in table 1:

Table 1. Reference details

SL No.	Authors	Year	Details
1	Lugert	2018	They assessed the status quo of value stream mapping from users perspective, necessity and possible ways for further development to ensure sustainability in the current situation of digitalization.
2	Kumar et al.	2018	They utilized Lean-Kaizen approach i.e., continuous eradication of process wastes through small changes which resulted in significant reduction of set up time, manpower, production lead time and value added time where value stream mapping was used for analyzing status quo and future state incorporating improvement suggestions.
3	Garza-Reyes et al.	2018	They proposed a PDCA-based sequenced approach to apply environmental value stream mapping effectively to pave the way to the sustainable green performance of operations.

SL No.	Authors	Year	Details
4	Arce et al.	2017	They took ergonomics conditions into consideration along with productive performance to be enhanced with the novel tool Ergonomic value stream mapping and conducted dual assessment on conventional productive performance and subjective mental workload.
5	Chen	2017	They presented an approach to enhance the efficiency of food traceability system by integrating value stream mapping and cyber physical system by fog computing network and suggests to incorporate artificial neural networks method for further validation.
6	Dadashnejad and Valmohammadi	2017	They assessed the influence of improvements suggested by value stream mapping analysis on overall equipment effectiveness (OEE).
7	Meudt et al.	2017	They extended the proven methods of Lean production to a six-step value stream mapping 4.0 to grab opportunities of more efficiency in current situation of digitalization of production.
8	Shou et al.	2017	They conducted a cross-sector review of development of value stream mapping in including manufacturing, health care, construction, product development and service sectors to differentiate between approaches in various sectors to create better understanding and development of value stream mapping and its more successful application.
9	Seth et al.	2017	They applied Lean in a complex production environment with some approximation and simplification in value stream mapping applications and established that broad Lean messages are independent of environment complexities. Their study also provides guidelines to adopt Lean in engineer to order (ETO) and high-mix low-volume (HMLV) environments.
10	Gunduz and Naser	2017	They undertook a cost based approach in integration with Line of Balance to apply value stream mapping in underground pipeline construction project with a view to adding sustainability and reducing value stream costs.
11	Rodriguez et al.	2016	They used a simulation based experimental design to implement Lean production in combination with human resource practices and resulted in enhanced job autonomy, job satisfaction, and operational performance. Result also showed that there is positive relationship between job autonomy and job satisfaction and between job satisfaction and operational performance.
12	Ramadan et al.	2017	They used real-time manufacturing cost tracking system to overcome the shortcomings of costing system in traditional value stream mapping incorporating Lean Manufacturing with Radio Frequency Identification (RFID).
13	Kumar	2016	He aimed at developing a general methodology to implement Lean Manufacturing tools in garment industry by restructuring sewing room using value stream mapping analysis and applied cellular manufacturing to add high flexibility.
14	Ciarapica et al.	2016	They attempted to bridge this gap between new product development practices and project success by investigating the difference between current and best practices, the underlying reason and defined measures to overcome the difference making the use of value stream mapping in a new product development project.
15	Vinodh et al.	2016	They proposed an integrated approach with value stream mapping and life cycle assessment analyzing societal, economic and environmental impact.
16	Henrique et al.	2016	They proposed a new approach for value stream mapping to get rid of the process wastes and bottlenecks in hospital environment which couldn't be realized by other mapping tools.
17	Ali et al.	2015	They combined value stream mapping with simulation modeling to help in better decision making about the implementation of VSM than which can be achieved using prediction tool for analyzing likely impact of improvement.

SL No.	Authors	Year	Details
18	Helleno et al.	2015	They used collective use of value stream mapping and discrete event simulation to make best decision between two improvement proposals.
19	Faulkner and Badurdeen	2014	They took an attempt to develop a sustainable value stream mapping by identifying and including additional metrics to evaluate the environmental and societal performance and validated the approach by applying it in a manufacturing line.
20	Forno et al.	2014	They conducted research on 57 papers, found out problems that hinders the process of successful implementation of Value stream mapping, the caused behind the problems and presented some guidelines for current state planning and construction.

From the above discussion, it's seen that there exists significant work on value stream mapping and Lean Manufacturing from various aspects but there is little work on financial feasibility justifying the approach using value stream mapping tool which is why this paper aims to contribute in this area.

3. Methodology

The methodology that was followed to conduct this research given in figure 1:

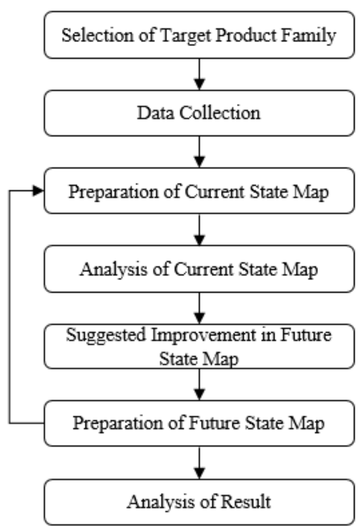

Figure 1. Methodology followed in the research

3.1 Selection of Target product Family

The furniture industry under this study mainly produces beds, sofas, chairs, tables and office appliances. The whole industry is consisted of 6 sections which are further divided into many operations in each section. There are fragmented numerous product lines which are defined by production planning department depending on orders and demand forecast. Moreover, these product lines are not always continuous between two subsequent sections. It won't be convenient to work with the whole industry with all these product lines of 6 products. As Among the products, sofas are one of the most time consuming and costly products so they were selected to work with. Again, considering all the 6 sections to produce a final product of sofa would not be convenient and effective as Lean is a brand new approach in this industry. As recommended by Rother and Shook (1999), the approach of VSM should be move backward that means from customer to upstream. For sofa, the next section to customer in backward direction is upholstery. Therefore this section was selected to commence the initiative. In upholstery, generally 3 or 4 production line run per day on parallel basis. Volume, cost and lead times of all the product families under this section were studied and it was found out that processing time for different product families were more or less the same. So, it was okay to work with any one of them. For this reason, this research is proceeded based on the data of King Sofa which can be used as generalized data for all the product families in upholstery section.

3.2 Data Collection

Data necessary for the study (both qualitative and quantitative) was collected from upholstery production floor during the course of regular production period. The first step that was taken in data collection was to determine the process flow diagram through which units flow from downstream to upstream in upholstery section. The flow diagram is given portrayed in figure 2:

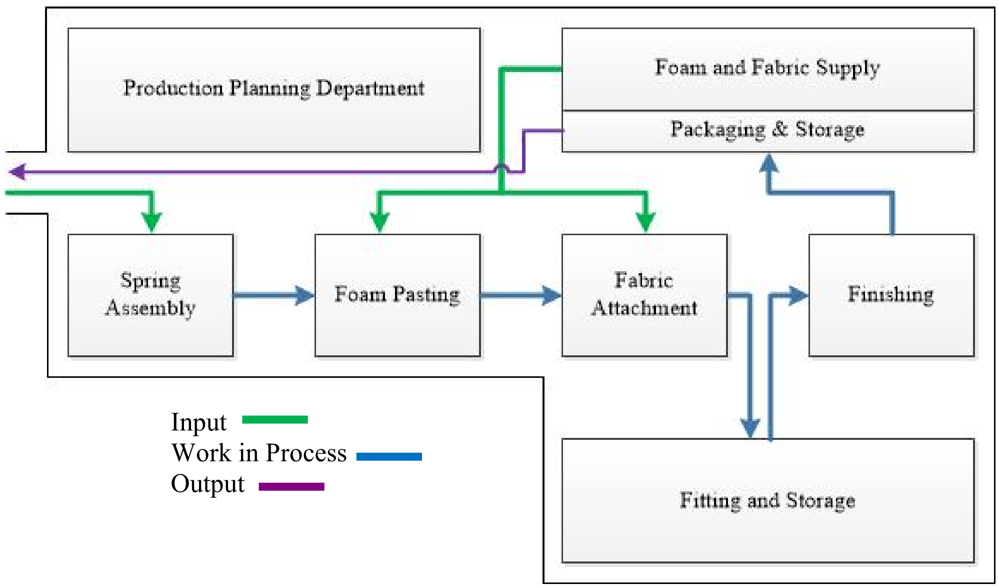

Figure 2. Current process flow diagram in upholstery section

The next step is to determine the values of key process factors like:

a) Cycle time (time required to complete a process)
b) Value added time (time taken for activities that directly add value to obtain the end product),
c) Non-value added time (time taken for activities that don't directly add value to obtain the end product),
d) Changeover time (time required to set up, installation or change tool, workpiece, programming etc.)
e) Manpower needed (workforce needed to complete a process)
f) Distance travelled (distance that the workpiece need to travel to reach the process station)

To get these values, the processes were observed and recorded with the help of stop watch 5 times for each process, and the mean value was taken. While collecting data for the research, as by Rother and Shook (1999), data was first collected from shipping, moving backwards in the manufacturing processes that a working unit needs to go through to raw materials or suppliers. "Snapshot" data was collected to document information on inventory levels (McDonald et al., 2002). The values of process factors obtained from the production floor is summarized in table 2 where all the times and distances are in minutes and meters respectively:

Table 2. Data for each production stage

Process Stage / Attributes	Spring Assembly	Foam Pasting	Fabric Attachment	Fitting	Finishing	Packaging
Cycle Time	47	45	90	9	18	11
Value Added Time	38	41	74	8	17	9.5
Changeover Time	2.5	.5	3.5	.5	.5	.5
Manpower Needed	1	1	1	2	2	2
Distance Travelled	3	1	1	5	5	2

The customer requirement is determined by demand forecast and orders placed by production planning department and according to them, it requires 10 sets to be completed per day. Production planning department receives information from marketing and sales and determines customer requirements. Then necessary schedules are prepared which is sent to supervisors responsible for each floor to implement the job. Orders are placed for foam and fabric department as needed. Another input of upholstery floor is sofa frame which is also supplied in accordance with the schedules provided by the planning department. Workers work in only one shift with a 15 minutes tea break and an hour lunch break. A day-by-day monitoring system is maintained to track the harmony of production with schedules. Cost items include labor cost, materials cost, production support cost, equipment cost and all of them are direct value stream cost which were collected on weekly basis. Some of the cost related data were assumed as all of these data are not accessible for all.

3.3 Preparation of the current state map

Once a product family is selected and necessary data is collected, the next step is to prepare the current state map of the existing process. Current state map was initially prepared using various value stream icons to portrait information and material flow throughout the production line by hand on paper. When the final map is reached, it was prepared finally by using SmartDraw software. The data boxes contain cycle time, changeover time, available time, uptime, distance and operators. The material and information flow are also noted to connect different parties and processes using arrows. There are two components in the timeline at the bottom of the map. The first component is the processing time and second component is inventory time. The value added time, non-value added time and PCE are also noted at the end of the timeline. Value added time is calculated by the addition of processing time for each process. Total inventory time is indicated as built-in non-value added time. Inventory storage, production push and pull in between the stages are indicated by triangle, striped arrow and semi round arrow icons respectively. The current state map is demonstrated in figure 3:

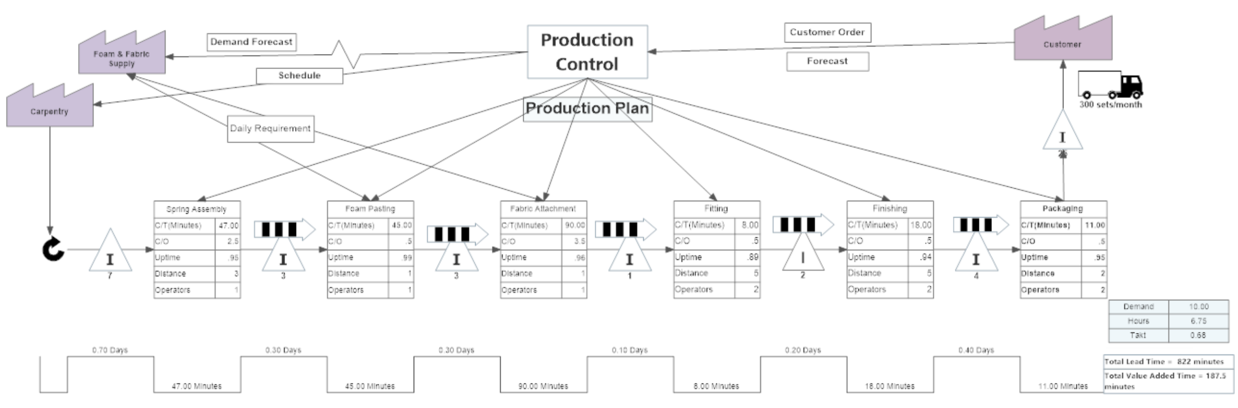

Figure 3. Current state map of existing process

Costs that contribute directly to the current state map in figure 3 are considered as value steam costs which are listed in table 3. These costs are calculated on weekly basis. The total cost is BDT 633620 for the current state. This research would suggest a future state map that would reduce this cost and increase capability to compete in market.

Table 3. Cost of current state activity

Process	Worker Cost, BDT	Production Support Cost, BDT	Equipment Cost, BDT	Material Cost, BDT	Total Cost, BDT
Spring Assembly	2750	3500	6000	20170	32420
Foam Pasting	2750	4000	9450	153576	169776
Fabric Attachment	2750	4000	7200	367000	380950
Fitting	5500	4000	13554	0	23054
Finishing	5500	3000	250	270	9020
Packaging	5500	2000	100	10800	18400
				Total	633620

3.4 Data analysis of the current state map

From the current state map the total value added time is 187.5 minutes. The production lead time is the summation of inventory times. The inventory time is obtained by multiplying the individual number of inventory units with the processing time of corresponding process. The Process Cycle Efficiency (PCE) is obtained by dividing value added time by production lead time which is 22.81%. It shows that value added time is only a small percentage of the total lead time. So, wastages have to be reduce to sync pace of production with demand.

TAKT time can be useful in this regard. TAKT time is determined by dividing available time per day with targeted output per day. As shift=1 (8 hours), lunch break= 1hour, tea break=15 minutes, hence available time=8-1-.25=6.75hours. Hence, TAKT Time= (Available time)/Demand =6.75/10=.68 hours.

From the data collected it was observed that spring assembly, foam pasting, fabric attachment process takes time higher than the TAKT time which hampers continuous production and are bottlenecks for the entire process. As there was considerably large number of inventories, the inventory time was calculated by multiplying inventory number with TAKT time.

For example, for inventory before Foam Pasting Operation, Inventory or Waiting time=3*.68*60=1206 minutes.
And also uptime for each station was calculated which refers to the percentage of processing which is spent to getting the equipment or workpiece ready for operation-
Uptime= (Cycle Time-Changeover time)/ (Cycle time)
For example, For Spring Assembly operation, Uptime= (47-2.5)/47=.95

3.5 Suggested Improvement in future state map

Development of the future state map actually starts at the time of the analysis of the current state map while shortcomings and areas of improvements are sought out. Several shortcomings were found out in the current state map of figure 3 and solutions are suggested below to overcome them.

3.5.1 Pull system

From the current state map it is observed that inventory time contributes the lion's share of the non-value added time. So to increase PCE it's essential to reduce the inventory in different points of the production line. Adaptation of Lean can be impactful as according to this philosophy nothing is produced until it is needed. Introduction of production pull system can implement this and reduce the inventory level considerably. For this purpose, Kanban-based system is suggested. Each process station will receive schedule from planning department and upstream will pull units from downstream maintaining FIFO (First In First Out). When a new unit is passed for processing in any process, production Kanban will pass signal to the preceding process to process another unit. Safety inventory of one unit is maintained for each process as a buffer in case any unpredicted interruption happens. Withdrawal Kanban is used to maintain systematic dispatch of raw materials and end products. When raw material supply receives signal by withdrawal Kanban, the materials will be provided directly to the process station as needed. Another suggestion is to introduce Supermarket which is a value stream mapping tool of the pull system that assists to signal demand for the product at the downstream end and that means the end of production chain or at the upstream end that means the beginning of the production chain and the lattermost workstation starts processing the final product at a pace of TAKT time (Rother and Shook, 1999). When materials or units are withdrawn from the supermarket, it triggers a signal for downstream workstation to fabricate new units to supplement the units withdrawn from the supermarket. A Kanban signal can also be used by the dispatching department to authorize and approve the stroll of the units from the supermarket (Grewal, 2008). Supermarket is suggested in the two ends of process stream efficiently to receive sofa frame inputs and dispatch final output having a control over inventory level.

3.5.2 Synchronization with TAKT time

To ensure continuous flow of work over the production floor, it is necessary to synchronize cycle time with the rhythm of TAKT time. From table 2, the cycle time for spring assembly, foam pasting and fabric attachment is more than the TAKT time. These three processes are process bottlenecks as their capacity is less than required. To reduce cycle time, reduction in set up time, minimization of wastage like transportation, inventory, simplification of operation, application of 5S were focused on. Again from table 2, the cycle time for fabric attachment is more than twice of the TAKT time. So, it's suggested to add another worker to reduce cycle time in this station.

3.5.3 Combination of process

The cycle time of fitting, finishing and packaging is way less than the TAKT time. So, resources in these stations are underutilized. It is suggested to combine these three process. As result, these three processes will be executed within one set up engaging the same workers which will result in the reduction of set up time, space, power engagement and increase equipment and manpower utilization. To apply this suggestion, it's necessary to ensure that the workers engaged in the combined station has the competency to carry out the activities of the previous three processes combined in one process in this recommendation.

3.5.4 Simplification and modification of work design

In spring assembly, two ends of the sofa frame needs to be marked properly to attach the spring along two end. The worker marks both ends with ruler. It takes time because the marking has to be accurate and done by some calculations to divide the ends in equal distances. This can be simplified by using a pre-marked piece of wood made for each specific product family to mark one end and marking the other by positioning the ruler vertically. The clothes and springs in spring assembly section are cut during processing each item which takes two workers and hampers the works of both of them. This work needed for the whole day can be performed once at the beginning of the day. It could reduce unnecessary motion and breakage in the pace of work. The foam for the foam pasting section is cut according to measurement differently for different product families in the supply section and are kept together in the foam pasting section. In the fitting section, hardware of different types are kept together. In both cases, the workers have to spend time to find the right one. 5S can be applied to earn more efficiency.

3.5.5 Layout modification

The current layout as in figure 2 is arranged is such a way that unnecessary time lost in transportation. To solve this, a modified layout of the processes are proposed as in figure 4 which can contribute in both reduction in transportation and prevent backflow of unit being processed.

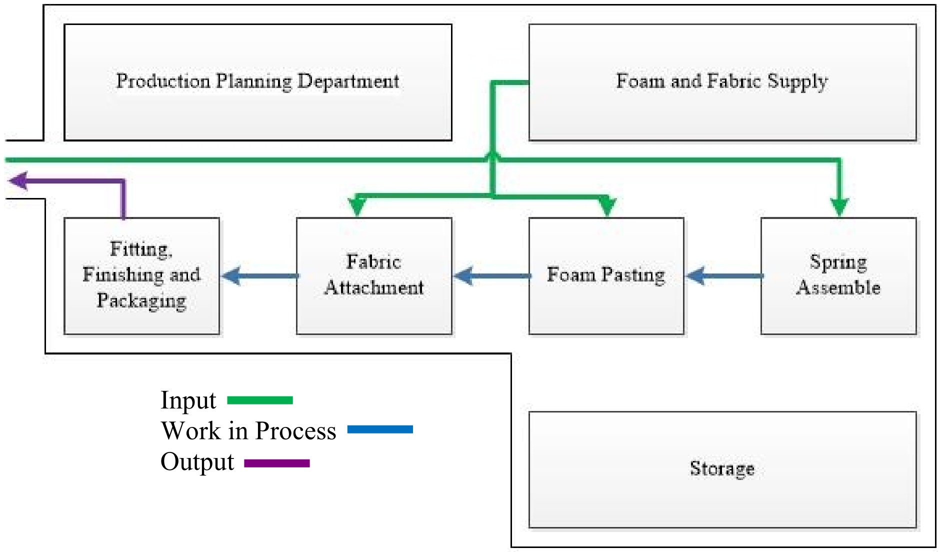

Figure 4. Modified process flow diagram in upholstery section

3.5.6 Redesign of process stations

It was seen that the necessary components, fabrics, foams were not in the station many times and they were not well arranged. In spring assembly, foam pasting and fabric attachment section, there are 6 work benches as shown in figure 4 among which 4 are used at most for work and the rest 2 remain idle. The workers working on different product families use their own basket and bench to keep necessary things without any systematic way. Again, some equipment are shared by different product families within a process station. So, a considerable amount of time was spent on fetching and searching them. Modification of process station arrangement can help in this regard. The redesign of stations are shown in figure 5:

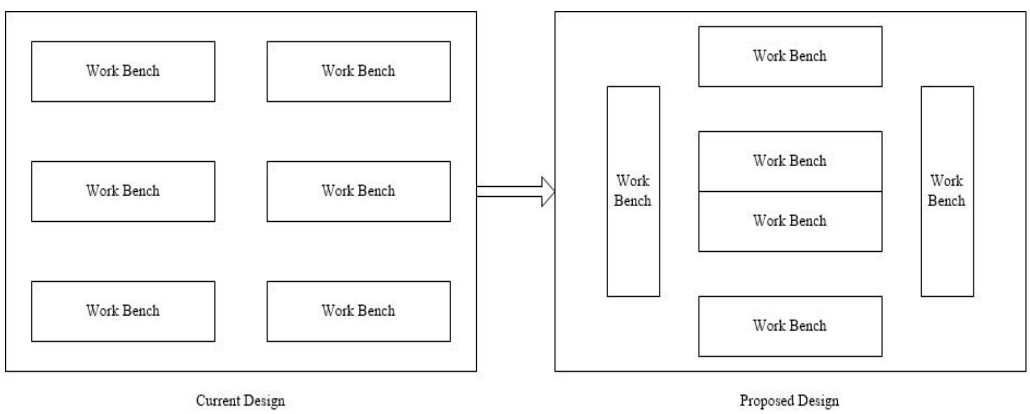

Figure 5. Redesign of process stations

3.5.7 Other supporting improvements

To extract the best outcome from value stream mapping, not only the production process but also the personnel attached to it, should adapt lean thinking. The workers, supervisors and each stakeholder should be trained about Lean philosophy and they have to be made ready to accept the changing environment. Not only that, they have to be made a part of the implementation process and any suggestions or opinion from them should be welcome and considered with value. Just to implement the future state map should not be the goal. There is always opportunity for further development. So, development of Lean in the industry should be a collective approach and Kaizen should be run on an ongoing basis.

4.6 Preparation of future state map

The future state map is prepared by implementing the suggested improvements to overcome the shortcomings of the current state map. It was assumed that all the related personnel are willing to adopt Lean. The Kanban system are indicated by box with arrow and the supermarket is indicated by E letter in reverse direction. Lightening bursts stands for the supporting improvements suggested. The future state map is illustrated in figure 6:

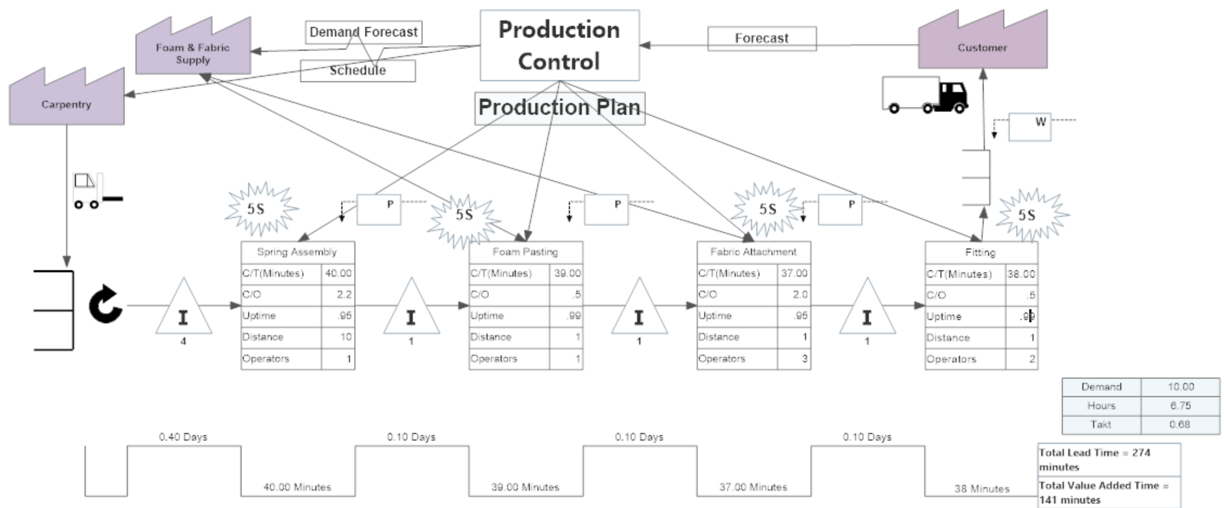

Figure 6. Proposed future state map

The financial impact of the proposed changes in the current state map can be assessed by the calculation of previously mentioned value stream costs in the future state map as illustrated in table 4. Then it was compared with the costs of current state map in table 3. It is observed that the total cost is reduced but 11.25%. It suggests that implementation of the suggested improvements will result in cost reduction and will contribute in industry's purpose to endure in the competitive market.

Table 4. Cost of future state activities

Process	Worker Cost, BDT	Production Support Cost, BDT	Equipment Cost, BDT	Material Cost, BDT	Total Cost, BDT
Spring Assembly	2750	2700	4833	16200	26483
Foam Pasting	2750	3400	7100	132000	145250
Fabric Attachment	6417	3550	5000	345080	360047
Combined	5500	3000	12150	9936	30586
				Total	562366

4. Result and Discussion

In this research value stream mapping in the upholstery section of a furniture industry as a commencement to adapt Lean thinking. To do that, a current state map was developed to identify and investigate process flaws and future state map was formulated incorporating the suggested improvements. By comparing current and future map, noteworthy improvements were noticed which is summarized in table 5:

Table 5. Production metrics comparison between current and future state map

Activity	Current state	Future State	Improvement
PCE (percentage)	22.81	51.5	28.69% Increased
Lead Time(minutes)	822	274	66.67% Decreased
No. of operators	9	7	22.22% Decreased
Production Capacity per day	8	12	50% Increased
Value added time (minutes)	187.5	141	24.8% Decreased
Non value added time (minutes)	316	296.5	6.17% Decreased

In the current state map there was high amount of inventories which was reduced in future state map by introducing production pull, supermarket, Kanban, synchronizing cycle time with TAKT time etc. The outcome was significant reduction in inventory time which is portrayed in figure 7:

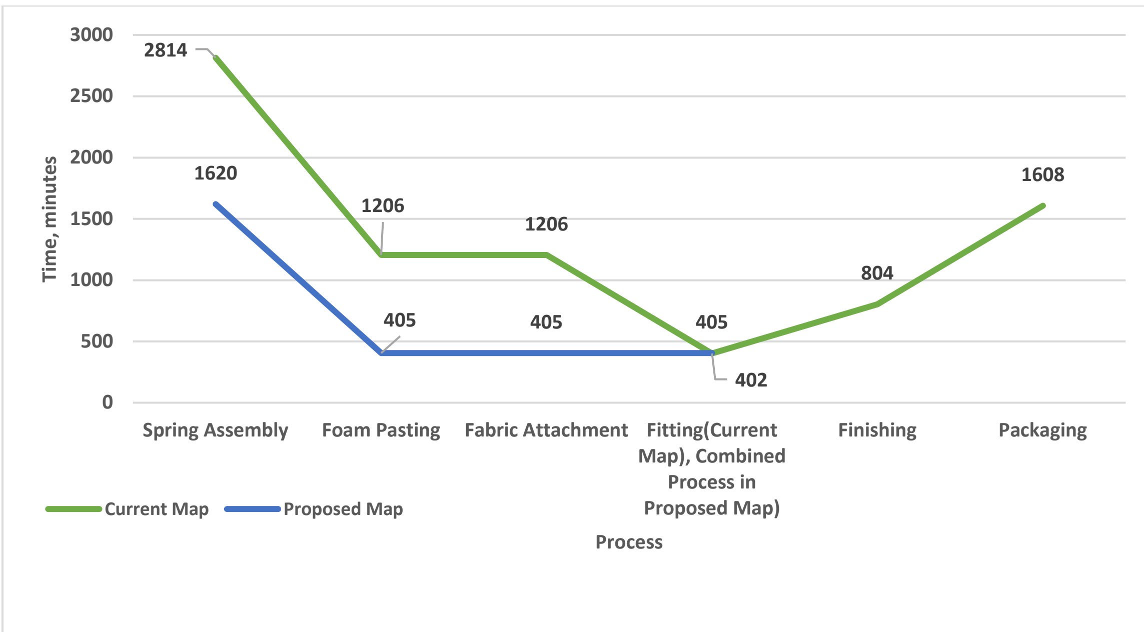

Figure 7. Comparison between inventory times

Due to the existing layout arrangement there was unnecessary movement which resulted in huge transportation waste in the current state map. The distance travelled to reach items from one process station to next was significantly removed by the modification of layout which is shown in figure 8:

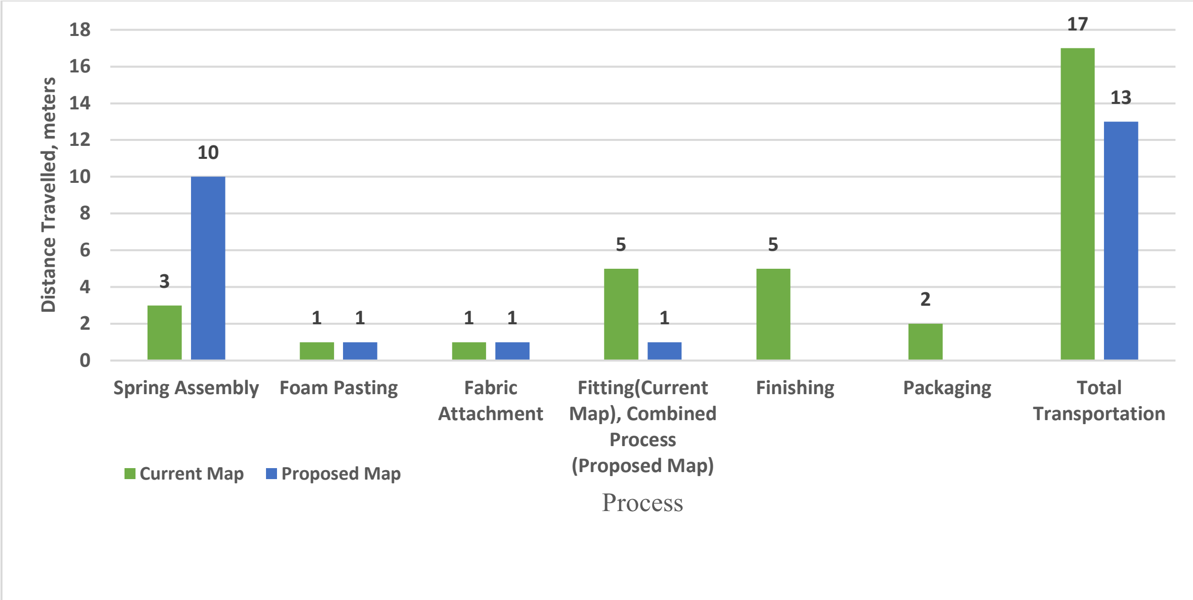

Figure 8. Comparison between distances travelled

Redesign of process stations, application of 5S, combination of processes etc. resulted in shorter set up time also. All these attempts led to shorter cycle time for each process. In current state three processes had cycle time more than TAKT time which hampered the continuous flow of work. But in the light of improvement proposed it was possible to keep the cycle times below the TAKT time to achieve the continuous flow which is illustrated in figure 9. This helped in synchronizing the cycle time with the pace of TAKT time.

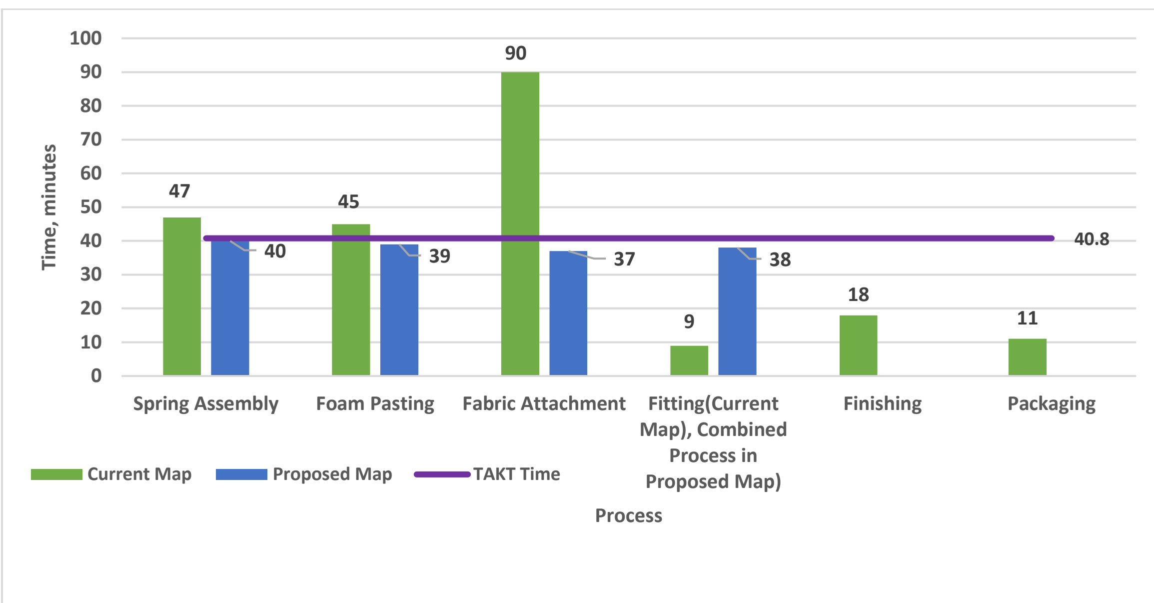

Figure 9. Comparison between cycle times with respect to TAKT time

The ultimate success of any industry is determined by the financial performance it's accomplishing. So, whether Lean should be adapted or not have to be justified economically which can be done by comparing table 3 and table 4 which proves that if the suggested improvements can be applied, it's possible for the industry to lower the value stream cost by 11.25%. The comparison between cost of current and future state map is further portrayed in figure 10 for more clarification.

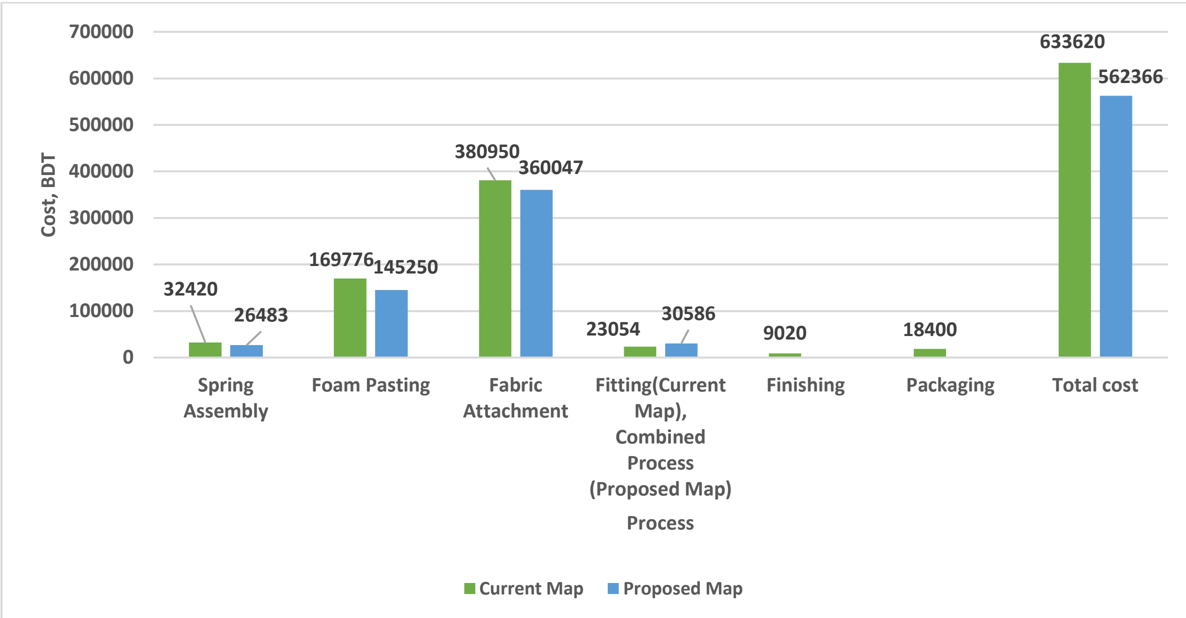

Figure 10. Comparison of costs between current and future state maps

Under the light of analysis and discussion stated here, application of Lean but the utilization of value stream mapping can be an effective approach for the industry to reduce production lead time, production cost and to minimize wastes that will contribute to enhance its competitive performance and achieve organizational goals.

5. Conclusion

Value stream mapping is an effective Lean tool that helps in the visualization of process under study to address the wastes and areas of improvements to pave the way of attainment of continuous flow from upstream to downstream of production resulting in reduced inventory, production cost and increased efficiency. To provide the industry under study with the favors of this Lean tool, this research attempts to utilize cost based value stream mapping in a real life case of the existing upholstery section of a furniture study and suggestions were proposed to improve process shortcomings. The execution of suggested improvements in the future state map is anticipated to result in 28.69% increase in Process Cycle Efficiency, 24.8% increase in total value added time, 60% decrease in non-value added time and 66.67% decrease in production lead time. In addition to that Cost based analysis is integrated which shows that implementation of future state map will result in 11.25% reduction in total cost on weekly basis. This attempt ascertains the economic viability of the proposed future state map. All these outcomes justifies the efficiency of value stream mapping in collaboration with cost implication in increasing customer response while also offering quality products to customers in relatively low price which enhance performance in competitive market environment.

The contribution of this research lies in the justification of financial feasibility of applying value stream mapping tool and incorporating suggested improvements following a systematic framework. The shortcoming of this research is the future state map is based on anticipation rather than application in real life situation. Moreover, in future state map, it was assumed that the employees are willing to adapt Lean and human factors in production were not considered. Some of the cost related data couldn't be collected accurately and were approximated due to industry policies and regulations. To overcome this limitations, further work can be done in this field by applying the suggested improvements in reality and incorporating simulation for evaluation. Additional focus can be laid on the implications of ergonomics and environmental factors in value stream mapping for better and more advanced outcome.

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