American Journal of Industrial and Business Management, 2018, 8, 1951-1971
http://www.scirp.org/journal/ajibm
ISSN Online: 2164-5175
ISSN Print: 2164-5167

Application of Lean Manufacturing in a Sewing Line for Improving Overall Equipment Effectiveness (OEE)

Shawkat Imam Shakil, Mahmud Parvez

Department of Industrial Engineering and Management, Khulna University of Engineering & Technology, Khulna, Bangladesh
Email: sowkotshakil@gmail.com

How to cite this paper: Shakil, S.I. and Parvez, M. (2018) Application of Lean Manufacturing in a Sewing Line for Improving Overall Equipment Effectiveness (OEE). *American Journal of Industrial and Business Management*, **8**, 1951-1971.
https://doi.org/10.4236/ajibm.2018.89131

Received: August 14, 2018
Accepted: September 24, 2018
Published: September 27, 2018

Abstract

The purpose of this paper is to implement lean in a sewing line, analyzing the layout, process flow and batch size, in order to improve Overall Equipment Effectiveness (OEE). To understand the overall performance and scope of improvement the existing layout and process flow are analyzed exquisitely. After that, the authors proposed a new layout reorganizing the process flow that eliminated backflows and reduced transportation time. The authors found that batch size has significant effect on waiting time and transportation time. Smaller batch size increases transportation time and decreases waiting time, and vice versa. For batch size optimization, summation of waiting time and transportation time for different batch size is calculated and the smallest one is selected as optimum. Through the application of reorganized process flow in proposed layout and optimum batch size, reduction in transportation time by 30.95% and increment in OEE by 3.75% have been achieved. Following the instruction of this paper, any organization can measure OEE and improve it by optimizing batch size, reorganizing process flows, redesigning layout and eliminating back flows. In this research the authors only redesigned layout, reorganized process flows and optimized batch size that lead to an improvement in OEE but it is still far behind as compared to world class OEE. Lean is enormous with its numerous tools and philosophies and it says that there is no ultimate destination on the improvement journey. There are many other tools and philosophies of lean which can be applied for further improvement.

Keywords

Lean Manufacturing, Process Flow, Optimum Batch Size, OEE, Lean Implementation

1. Introduction

Process waste reduction is one of the most important factors in companies' attempts to be successful and flourish in the competitive global marketplace with low profit approach. Waste refers to the activities which take advantage of partial resources without retaining any value [1]. Seven primary types of waste exist: defects, inventory, overproduction, transportation, waiting time, over processing, and excessive motion [2] [3] [4]. After World War II Japan faced scarcity of resources, materials and manpower. Lean manufacturing was first introduced then to cope with this problem [5]. A new process-oriented system was commenced by the Japanese industrial leaders, such as Shingo and Ohno, which is referred to as "Toyota Production System" or "Lean Manufacturing". Lean manufacturing focused on eliminating or reducing waste in all forms by applying effective and proven technique that ultimately lead to reduction in cost without compromising quality [6] [7]. Kaizen, Kanban, just in time (JIT), line balancing, layout redesign, cellular layout, and quality at the source are key lean manufacturing techniques though it is not limited to such tools. Applications of lean manufacturing have reached many industries, including automotive, electronics, and consumer products manufacturing. Examples can be found in Rajenthirakumar *et al.* (2011), Holweg (2007), Taj *et al.* (2006) [8] [9] [10].

The sewing industry is a part or component of the textile industry. Sewing requires the use of many operations, using sewing machines to assemble fabric pieces and attach various accessories like elastics, buttons, zippers, and labels. Rahman *et al.* (2016), and Shaeffer (2010) considered sewing as a labor-intensive industry because it depends heavily on labor skills and machine precision to perform a multitude of operations [3] [11]. Application of lean manufacturing is considered recent to textile industries as compared to the extensive implementation in other fields [12]. As a result, it will be interesting and challenging to implement lean manufacturing in the sewing industry. Lean allows manufactures to produce quality products with more efficiency and less time when it is implemented properly. Customers do not want to pay for the cost incurred due to the waste in the system and lean focuses on elimination of such waste. Nevertheless, there are various reasons for which many small manufacturers can't take advantage of lean. These manufacturers either have never been exposed to lean or just do not have the knowledge or knowhow to implement it. Some do not see value in sending employees to expensive training because of a lack of knowledge of what lean is and can do [13].

This paper presents an implementation of lean manufacturing in the sewing section. To identify key wastes in sewing and prescribe suitable lean techniques to reduce waste, backflow and provide improved overall operational performance one production line is selected in a sewing section in VIP INDUSTRIES BD PVT LTD. To represent current-state behavior a transportation and operation process flow layout is built to identify backflow in the sewing process. Relevant lean techniques are applied to reduce waste and future layout for transportation and operation process flow is developed to illustrate the improvement with no back flow.

Reorganization of process flow and redesign of layout are frequently needed activities in many of the sewing industries. A performance indicator or assessment tool is required for proving the efficacy of the changes. This research focused on such assessment by OEE which provides a sense of how well the operations are going on in response to the changes. This research also signified that how production can be enhanced just by focusing on batch size.

This research focused on the application of Lean Manufacturing in travel bag sewing section in VIP INDUSTRIES BD PVT LTD., as a strategy for improving Overall Equipment Effectiveness (OEE). The objectives include study and evaluation of current status of the line, application of lean manufacturing for improving OEE, determination of the extent of OEE and productivity after the application of lean manufacturing.

2. Literature Review

2.1. Lean Process and Principle

Toyota Production System first introduced lean approaches. But the concept was first appeared in a book named "*The Machine That Changed the World*" [14]; which mainly highlighted Japanese production methods as compared to traditional mass production systems. In the history of lean, the book named "*Lean Thinking*: *Banish Waste and Create Wealth in Your Organization*" was also a milestone contribution as it summarizes the lean principles and coined the phrase "lean production". The term "lean" refers to a series of activities or solutions to minimize or eliminate waste and Non Value Added (NVA) operations or activities, and improve the value added (VA) operations or activities. The Japanese production methods introduced this VA and NVA concepts, especially the Toyota Production System (TPS). MacDufile *et al.* (1997) has defined waste as anything that interferes with the smooth flow of production [15]. Overproduction, over processing, excess inventory, unnecessary movement, waiting time, defects, unused employee creativity and conveyance were highlighted in TPS as key wastes. Brintrup *et al.* (2010) also pointed those stated wastes in terms of value drivers to execute the improvement opportunities throughout the production and manufacturing process [16]. As a term "lean process" has many definitions in the literature. Shah and Ward (2007) defined lean process as an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing or minimizing supplier, customer, and internal variability [17]. Hopp *et al.* (2004) defined lean as the production of goods or services that minimizes buffering costs associated with excess lead times, inventories, or capacity [18]. According to Rother *et al.*, (1999), and Abdulmaleka *et al.*, (2007) lean production means identification of all types of waste in the value stream of supply chain and implementation of necessary tools to eliminate them for minimizing lead time [5] [19].

2.2. Lean Implementation Method

Incorrect application of lean methods leads to inefficiencies of associate organization's resources and reduced worker confidence in lean methods [20]. Therefore, applying the appropriate strategy at the appropriate time for the right processes is very important. The success of any explicit management strategy usually depends upon organizational characteristics, which suggests that each one organizations mustn't or cannot implement the same set of methods in their explicit case [21]. Anvari *et al.* (2010) projected eleven essential success factors (management and leadership, structure cultures, goals and objectives, drawback finding, skills, continuous improvement, monetary capabilities, performance measure, change, education and plan) for effective implementation of lean methods [22]. They planned 3 implementation stages (preparation, style and implementation) however didn't establish a scientific methodology by that makers may determine wastes; assess existing performance; take away those wastes; recalculate the performance and use appropriate lean tool for continuous enhancements. Wu *et al.* (2009) planned case primarily based four-step (problem finding, plan finding, obstacle finding and answer finding) downside determination approach to demonstrate how products cost and quality are affected by lean supply chain [23]. They used value stream mapping (VSM) as lean supply chain to reduce cost and lead time and enhance quality through P-D-C-A improvement cycle. Parry *et al.* (2010) developed a methodology that followed four steps: market analysis, visible values stream, customer values analysis and financial modeling [24]. Consideration of structure contexts are perceptibly lacking in analysis on implementation of lean ways. Despite the good potential of lean ways in performance improvement, there are several reports of failures due to confusion regarding the way to adopt tools in a very specific surroundings [25]. The implementation of inappropriate lean strategy for a given situation can sometimes lead to an increase in waste, cost and production time of a manufacturer. Because of inappropriate choice of lean ways, changes could cause disruptions in many processes it meant to boost. Therefore, it's crucial to find a scientific methodology to implement acceptable lean ways based on identifying waste in manufacturing processes. However, few tries are created to develop a structured methodology of implementing the acceptable lean ways. As makers seeking the recommendation for his or her investment in implementing new lean methods might need sure theoretical ground to assure that their investment choices are logically sound [26], it is necessary to develop a strategy to implement applicable lean ways beside correct methodology to judge the continual performance improvement. The concept of "Lean Production (LP)" became in style through the book "*The Machine That Changed the World*" by Womack and Jones in the year 1990. LP addresses elimination of waste and makes the process flow more efficient and economical [27]. Now in this current era of global competitiveness, not only the manufacturing organizations are facing enormous pressure from their customers and competitors but it is the challenge for other industries too.

All these factors have given means to integrate the LP thought with the entire production method (starting from the supplier to the delivery to the customer). This has given rise to the concept of "Lean Enterprise (LE)" [28]. LE does not restrict to organization but it extends beyond their limits.

2.3. Lean Assessment Methods

It is critical to evaluate the performance for realizing the advantages of lean practices. Many models and techniques had been developed by researchers to evaluate the performance of lean. Most of the researchers measured leanness of manufacturing through evaluation of productivity or operational efficiency. Measuring leanness and also the choice of right measuring metrics with applicable implementation technique is extremely crucial. Wan *et al.* (2007), Kuhlang *et al.* (2011) measured the lean performance through VSM in manufacturing organization [29] [30]. Wan *et al.* (2007) measured the overall leanness by VSM considering cost, time and output values however didn't contemplate the effectiveness of production compared to company objective [29]. On the other hand, Wu *et al.* (2009) measured only overall equipment effectiveness and failed to evaluate the efficiency as well as overall performance [23]. Fullerton *et al.* (2009) and Agus *et al.* (2012) used structural equation modeling (SEM) to establish the relationship between different lean tools and lean production performance [31] [32]. They conducted several surveys to validate the relationships. Wan and Chen (2008) addressed VSM, lean assessment tools and lean metrics as the 3 pillars of leanness measure [33]. Hon (2003) recommended four sorts of measures covering all aspects of business organizations and the measures are: market valuation, financial, non-financial and cost measures [34]. Various lean assessment surveys have additionally been conducted by lean practitioners and researchers like Fullerton *et al.* (2009), Karlsson *et al.* (1996) to assess the leanness [31] [35]. Most of their surveys had provided totally different lean indicators and checklists to assess the modification of existing system to lean. Results of the surveys are usually shown as scores presenting the variations between the present state of the system and the ideal conditions predefined in the surveys which give an outline of the extent of leanness. In comparison to qualitative surveys, quantitative metrics and models give higher leanness score. Researchers developed different strategies and techniques to quantify leanness in their literature. Wan and Chen (2009) developed a web-based lean implementation approach consisting of three implementation cycle referred to as lean training, VSM and lean assessment [36]. Bayou *et al.* (2008), Behrouzi *et al,* (2011), Wong *et al.* (2011) used fuzzy logic algorithmic rule to evaluate the manufacturing leanness since leanness are often measured considering quantitative as well as qualitative indicators with this algorithm measured manufacturing productivity by applying VSM and method time measurement (MTM) [37] [38] [39].

The specialty of this paper is the methodology of optimum batch size. Batch size optimization in such a way based on waiting time and transportation time can hardly be found or not in previous research. Batch size is an important issue in many of the manufacturing organizations. This way of optimizing batch size will be very effective especially for sewing industry where waiting time and transportation time have such relation like they are related in this paper work.

3. Methodology

3.1. Study Population

The workers and operators of VIP INDUSTRIES BD PVT LTD., which is located at Mongla EPZ, Baherhat-9351, Bangladesh, compose the study population. There were 8 sewing lines in that floor, among them line 2 was selected for carrying out the study. The team leader of that line, the supervisor and 24 sewers were the subjects of the study because they were the sources of relevant data through survey and interviews. The industry was cooperative with such project works and they gave opportunity to observe, interview the operators and record data. That's why it was selected for carrying out the project there.

3.2. Description of Respondents

The supervisor in line 2 was the most respondent of the study since he was answerable within the watching activities in stitching section. The sewers in every process were discovered and interviewed to assemble vital info as they directly involved in the production and operation system. All pertinent data and information related to process flow and operations were gathered from them through time study and questioning.

3.3. Research Instruments

Based on the outlined objectives, self-constructed interview guide, standardized forms such as Cycle Time Observation Form, Process Flow Chart, were the main instrument for data collection. These data and information were used in the development of the study.

3.3.1. Process Flow

Stitching operations of the Duffle Trolley (DFT) bag takes six inputs to the sewing line which are front part, side toton part, back part, U-part, top part and bottom part. Operation process is considered as one of the most important factors and very intensive study is carried out to understand the detailed process. After that a layout is developed showing all the existing process flows and transportations in Figure 1. For better understanding of the layout, the processing details according to the workstations are given in Table 1.

The proposed layout is shown in Figure 2, which gives a simple process flow where all the inputs are close to the input section except that the input at machine A10. For better understanding of the layout, the processing details according to the workstations are given in Table 2.

For 27 processing 30 machines are excess that results in 4 machines almost idle. As there are only 24 operators available in the sewing line and some of the processes require lower processing time, two processes can be assigned to some

Table 1. Existing process flow.

SL. NO.	A	B
1	Joining Logo part with Front part	Front part Lining
2	U-part Lining	Front part Piping
3	Zipper Joint with U-part	Top part Lining
4	Joining Side toton with Front part	Top & Back part Piping
5	Top and U-part joining through Zipper	Zipper joint with Front part
6	Looping Top part	Binding Top part
7	Side toton piping	Side toton Stitching
8	Used occasionally/Idle	Handle joining and Lining Front part
9	Trolley cover Lining and Zipper joining	Front part Piping
10	Used occasionally/Idle	Handle Joining with Back part
11	Two needle on Top and Bottom part (Gadget part)	Back part Lining
12	Lining Bottom part	Joining Gadget and Back part
13	Handle joining with Bottom part (Gadget part)	Add Front part with Combined part
14	Binding	Used occasionally/Idle
15	Cutting Excess String	Used occasionally/Idle

Table 2. Proposed process flow.

SL. NO.	A	B
1	Joining Logo part with Front part	Side toton Stitching
2	Front part Lining	Side toton piping + Front part Piping
3	Zipper joint with Front part	U-part Lining
4	Joining Side toton with Front part	Zipper Joint with U-part
5	Handle joining and Lining Front part	Top part Lining
6	Available for balancing operations	Top part Piping + Front part Piping
7	Handle Joining with Back part	Top and U-part joining through Zipper
8	Back part Lining	Binding Top part
9	Trolley cover Lining and Zipper joining	Looping Top part + Back part Piping
10	Handle joining with Bottom part (Gadget part)	Available for balancing operations
11	Lining Bottom part	Two needle on Top and Bottom part (Gadget part)
12	Add Front part with Combined part	Joining Gadget and Back part
13	Binding	Cutting Excess String

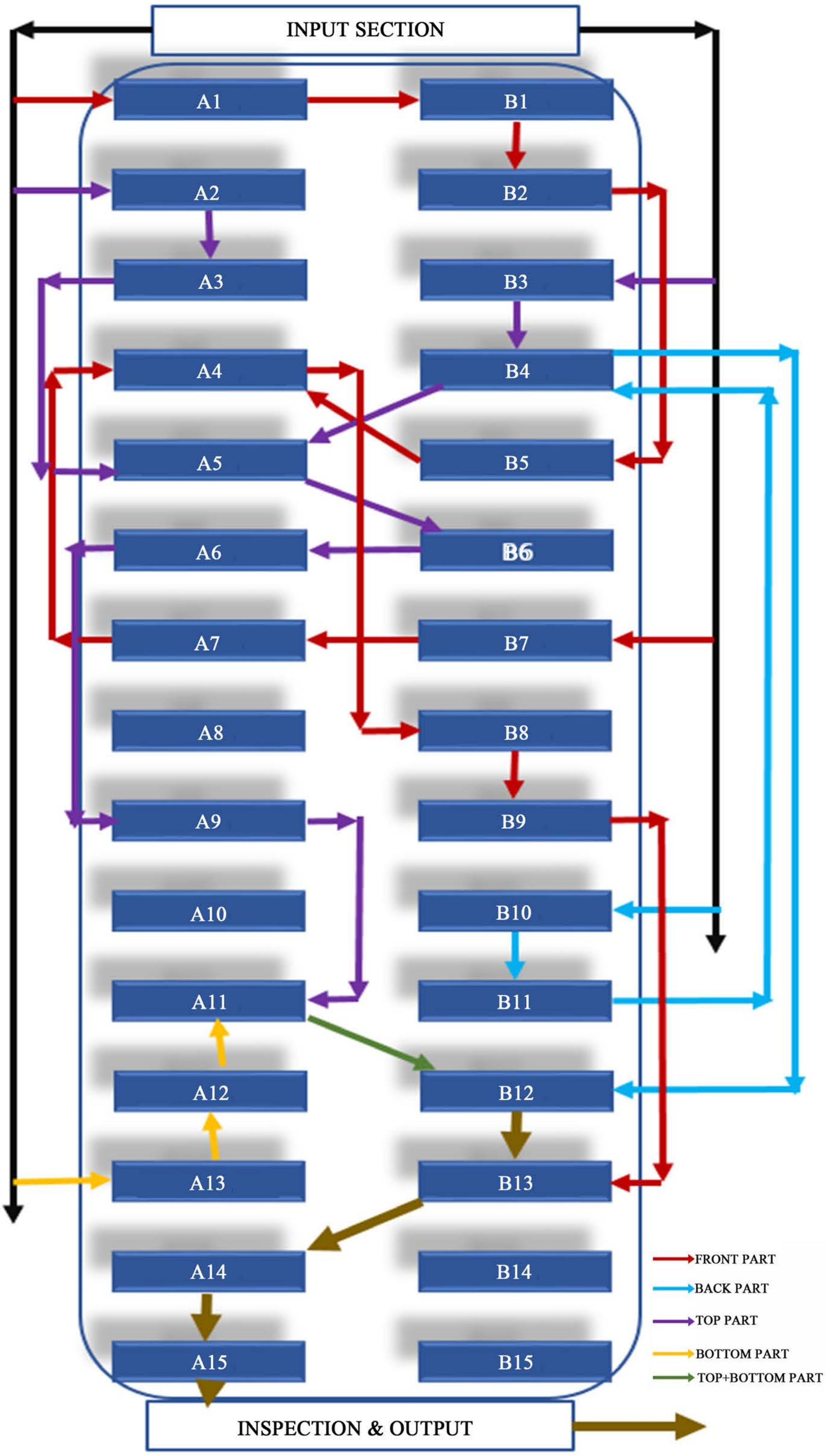

Figure 1. Existing layout.

machines. The new layout is proposed using 26 machines among them 2 machines are kept for balancing the operations and other 24 machines are for continuously operating by the sewers.

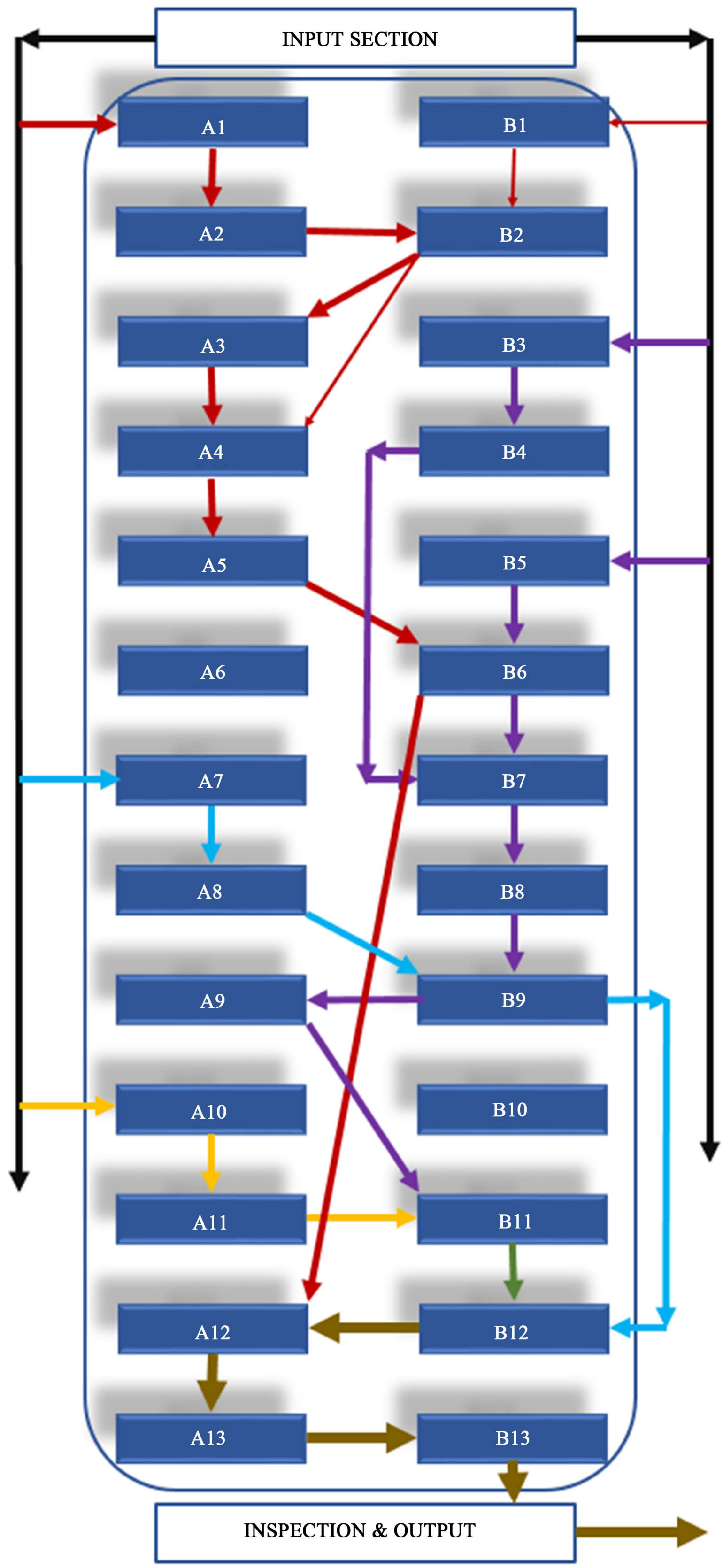

Figure 2. Proposed layout.

3.3.2. Batch Size

In VIP INDUSTRIES, current batch size in sewing line 2 is 60 pieces. This large batch size results in huge waiting time and currently they are trying to balance this by moving operators from one machine to another that ultimately results in a haphazard situation and waiting time is not reduced. Also when this large batch size contains any defects it increases the transportation time.

For analyzing the effectiveness of smaller batch size, waiting time for respective batch sizes should be calculated. In line 2, this waiting occurs once in a lead time (4 weeks) as once the next worker gets work, processing continues and he/she doesn't have to wait for the next batch after completing the current one. Waiting time in a lead time should be converted to the waiting time per bag. For a batch size, waiting time per bag may be smallest but can't be selected immediately because optimum batch size depends on both transportation time and waiting time. Though smaller batch size has positive effect on waiting time, at the same time it has negative effect on transportation time. Transportation time increases when batch size decreases. Transportation time for a batch size of 30 pieces will be double of transportation time for a batch size of 60 pieces. Hence a trade-off is required between waiting and transportation time.

Methodology for the selection of optimum batch size:

- Calculate transportation time per bag for a batch size.
- Calculate waiting time per bag for a batch size.
- Calculate summation of waiting and transportation time per bag for that batch size.
- Select the batch size having lowest summation of waiting and transportation time per bag.

3.3.3. Overall Equipment Effectiveness (OEE)

OEE stands for Overall Equipment Effectiveness. It is the product of three subcomponents of manufacturing process—Availability, Performance and Quality. It is a simple manufacturing metric which provides easy understanding of the current status of the manufacturing process and also a complex tool which allows understanding the effect of the various issues in the manufacturing process and how they affect the entire process.

OEE = Availability × Performance × Quality.

OEE shows the scope of improvement. The individual percentage of availability, performance and quality helps deciding which factor to be emphasized for improving OEE.

Availability refers to the machine or worker being available for production with respect to the scheduled time.

$$\text{Availability} = \text{Run Time (RT)}/\text{Planned Productive Time (PPT)} \qquad (1.1)$$

Run Time is part of Planned Productive Time which is effectively used. It excludes Stop Time from Planned Productive Time, where Stop Time is defined as total time when the manufacturing process was intended to be running but was not due to Unplanned Stops or Planned Stops.

Performance is the speed at which the operations are carried on. Performance here is the ratio of Net Run Time to Run Time, where Net Run Time is the product of Ideal Cycle Time to Total Count.

$$\text{Performance} = [\text{Ideal Cycle Time (ICT)} \times \text{Total Count (TC)}]/\text{Run Time (RT)} \quad (1.2)$$

Quality is the measure of how accurate the system or process is to the input.

$$\text{Quality} = \text{Good Count (GC)}/\text{Total Count (TC)} \quad (1.3)$$

Now,

$$\text{OEE} = [\text{RT}/\text{PPT}] \times [(\text{ICT} \times \text{TC})/\text{RT}] \times [\text{GC}/\text{TC}]$$

Hence, the simplified equation of OEE is:

$$\text{OEE} = (\text{ICT} \times \text{GC})/\text{PPT} \quad (1.4)$$

Here, Ideal Cycle Time and Planned Productive Time are fixed, so only Good Count has significance on OEE. Good Count will be increased when any one of OEE factors will be increased. More availability will offer more time to produce more products, greater performance will lead to completion of more products, and higher quality will reduce defects that will increase good products.

4. Data Analysis

4.1. Calculation of Transportation Time

Moving time for unit distance (distance between parallel workstations or machines) is 2 seconds. For cross distance between two machines, one unit distance is considered as extra. Perpendicular distance from machine A1/B1 to input section is 2 units. Loading and unloading time is 6 seconds.

Hence, transportation time for A1/B1 to Input section = $(2 \times 2) \times 2 + 6$
= 14 seconds.

For B1 to B2 = $(1 \times 2$ seconds$) \times 2 + 6$ seconds
= 10 seconds.

For B2 to A3 = $(2 \times 2$ seconds$) \times 2 + 6$ seconds
= 14 seconds.

Multiplication of 2 with moving time addresses going and returning of sewer.

In this way transportation time for the existing and proposed layout is calculated and given in Table 3.

WS = Work Station, EL = Existing Layout, PL = Proposed Layout, TT = Transportation Time are the notations used in Table 3.

For existing layout, TT per bag = 588/60 = 9.8 seconds.

For proposed layout, TT per bag = 406/60 = 6.77 seconds.

As current batch size is 60 pieces.

4.2. Calculation of Optimum Batch Size

Cycle time (CT) is the time starting when an operation begins to the point of time when the operation ends. Average Cycle Time for 27 sewing processes of the DFT bag is given in Table 4.

Table 3. Transportation Time (per batch) for existing and proposed layout.

Processes	WS - EL	WS - PL	TT - EL (Sec.)	TT - PL (Sec.)
Joining Logo part with Front part	A1	A1	14	14
Front part Lining	B1	A2	10	10
Front part Piping	B2	B2	10	10
Zipper joint with Front part	B5	A3	18	14
Side toton Stitching	B7	B1	38	14
Side toton Piping	A7	B2	10	10
Joining Side toton with Front part	A4	A4	30	10
Handle joining and Lining Front part	B8	A5	26	10
Front part Piping	B9	B6	10	14
Top part Lining	B3	B5	22	30
Top part Piping	B4	B6	10	10
U-part Lining	A2	B3	18	22
Zipper Joint with U-part	A3	B4	10	10
Top and U-part joining through zipper	A5	B7	28	18
Binding Top part	B6	B8	12	10
Looping Top part	A6	B9	10	10
Trolley cover Lining and Zipper joining	A9	A9	18	10
Handle joining with Bottom part (Gadget part)	A13	A10	62	50
Lining Bottom part	A12	A11	10	10
Two needle on Top and Bottom part	A11	B11	24	10
Handle Joining with Back part	B10	A7	50	38
Back part Lining	B11	A8	10	10
Back part Piping	B4	B9	34	14
Joining Gadget and Back part	B12	B12	50	18
Add Front part with Combined part	B13	A12	32	10
Binding	A14	A13	12	10
Cutting Excess String	A15	B13	10	10
	Total time		588	406

Table 4. Average cycle time.

Sl. No.	PROCESS	CT 1 (Sec.)	CT 2 (Sec.)	CT 3 (Sec.)	Avg. CT (Sec.)
1	Joining Logo part with Front part (INPUT)	22.00	22.00	23.00	22.33
2	Front part Lining	57.00	55.00	58.00	56.67
3	Front part Piping	64.00	62.00	65.00	63.67
4	Zipper joint with Front part	25.00	28.00	25.00	26.00

Continued

5	Side toton Stitching (INPUT)	17.00	18.00	16.00	17.00
6	Side toton piping	30.00	29.00	29.00	29.33
7	Joining Side toton with Front part	39.00	40.00	38.00	39.00
8	Handle joining and Lining Front part	60.00	58.00	60.00	59.33
9	Front part Piping	78.00	73.00	77.00	76.00
10	Top part Lining (INPUT)	24.00	21.00	22.00	22.33
11	Top part Piping	30.00	30.00	31.00	30.33
12	U-part Lining (INPUT)	34.00	31.00	32.00	32.33
13	Zipper Joint with U-part	51.00	50.00	51.00	50.67
14	Top and U-part joining through Zipper	51.00	50.00	49.00	50.00
15	Binding Top part	31.00	30.00	32.00	31.00
16	Looping Top part	12.00	11.00	13.00	12.00
17	Trolley cover Lining and Zipper joining	80.00	79.00	77.00	78.67
18	Handle joining with Gadget part (Bottom part) (INPUT)	27.00	26.00	29.00	27.33
19	Lining Bottom part	36.00	36.00	39.00	37.00
20	Two needle on Top and Bottom part (Gadget part)	98.00	99.00	99.00	98.67
21	Handle Joining with Back part (INPUT)	25.00	24.00	23.00	24.00
22	Back part Lining	102.00	101.00	99.00	100.67
23	Back part Piping	57.00	54.00	55.00	55.33
24	Joining Gadget and Back part	33.00	33.00	35.00	33.67
25	Add Front part with Combined part	60.00	64.00	61.00	61.67
26	Binding	26.00	27.00	26.00	26.33
27	Cutting Excess String	85.00	87.00	86.00	86.00
	Total time in 27 processes				1247.33
	Average processing time of 1 bag				46.20

Average processing time of 1 bag (with 10% allowance) = 46.20 × 1.1 = **50.82** sec.

Current batch size in line 2 is 60 pieces and it is considered as reference batch size. Hence, batch size smaller than 60 pieces will have lower waiting time and higher transportation time and vice versa. For 60 pieces batch size, a dependent process waits for the completion of its previous process by 60 times of its processing time. Waiting Time (WT) for different batch sizes are given in **Table 5**.

Here, batch size 30 pieces is smallest which have smallest processing time. But it is not optimum batch size because it will have higher transportation time. To obtain optimum batch size transportation time for each batch size should be calculated and the batch having lowest summation of waiting and transportation time should be selected (**Figure 3**).

Transportation time per batch in proposed layout is 406 sec. or 6.77 sec. per bag									
Batch size 60 is considered as reference, TT & WT are for one bag in sec.									
Considered Batch Sizes				70	60	50	40	30	
BATCH SIZE OPTIMIZATION									
70 PIECES		60 PIECES		50 PIECES		40 PIECES		30 PIECES	
TT	WT	TT	WT	TT	WT	TT	WT	TT	WT
5.80	22.26	6.77	19.08	8.12	15.90	10.16	12.72	13.54	9.54
Total	28.06	Total	25.85	Total	24.02	Total	22.88	Total	23.08
Optimum Total Time									22.88
Optimum Batch Size									40 PIECES

Figure 3. Excel sheet format for optimum batch size.

Table 5. Waiting time for different batch sizes.

SL. No.	Avg. CT with Allowance (Sec.)	WT 60	WT 70	WT 30	WT 40	WT 50
1	24.57	0	0	0	0	0
2	62.33	1474	1719.67	737	982.67	1228.33
3	70.03	5214	6083	2607	3476	4345
4	28.6	9416	10985.33	4708	6277.33	7846.67
5	18.7	0	0	0	0	0
6	32.27	1122	1309	561	748	935
7	42.9	3058	3567.67	1529	2038.67	2548.33
8	65.27	5632	6570.67	2816	3754.67	4693.33
9	83.65	9548	11139.33	4774	6365.33	7956.67
10	24.57	0	0	0	0	0
11	33.37	1474	1719.67	737	982.67	1228.33
12	35.57	0	0	0	0	0
13	55.73	2134	2489.67	1067	1422.67	1778.33
14	55	5478	6391	2739	3652	4565
15	34.1	8778	10241	4389	5852	7315
16	13.2	10824	12628	5412	7216	9020
17	86.53	11616	13552	5808	7744	9680
18	30.07	0	0	0	0	0
19	40.7	1804	2104.67	902.00	1202.67	1503.33
20	108.53	4246	4953.67	2123.00	2830.67	3538.33
21	26.4	0	0	0	0	0
22	110.73	1584	1848	792	1056	1320
23	60.87	8228	9599.33	4114	5485.33	6856.67
24	37.03	11,880	13,860	5940	7920	9900
25	67.83	14,102	16452.33	7051	9401.33	11751.7
26	28.97	18,172	21200.67	9086	12114.7	15143.3
27	94.6	19,910	23228.33	9955	13273.3	16591.7
Total WT	1372.07	155,694	181,643	77,847	103,796	129,745
WT/bag	50.82	19.08	22.26	9.54	12.72	15.90

4.3. Calculation of OEE

We will start with the calculation of existing OEE. After that proposed OEE will be calculated based on the proposed process flow and batch size.

4.3.1. Existing OEE

Shift Length = 10 hours = 10 × 60 min = 600 min.

Breaks = 1 hour = 60 min.

Planned Productive Time (PPT) = 600 min − 60 min = 540 min.

Run time (RT) = PPT − (setup + breakdown).

Thread changing and bobbin positioning time = (40 × 12 × 6)/60 min = 48 min.

Here, Changing and positioning takes about 40 seconds which takes place 12 times in a 60 pieces batch size and in a shift about 6 batches are completed.

Lubrication time = 12 min.

Breakdown time = 30 min.

Hence, RT = 540 min − (48 + 12 + 30) min = 450 min.

Actual Cycle time = Processing time with allowance + TT + WT
= (50.82 + 9.8 + 19.08) second
= 79.7/60 min
= 1.33 min.

Total Count = 340 bags.

Defects = 16 bags.

Good Count = 324 bags.

Table 6 shows Ideal Cycle Time (ICT) which is the fastest cycle time that a process can achieve in optimal circumstances for each process.

From Equation (1.4)

OEE = (ICT × GC)/PPT;

Availability = RT/PPT = 450/540 = 0.8333;

Performance = (ICT × TC)/RT = (0.75 × 340/450) = 0.5667;

Quality = GC/TC = 324/340 = 0.9529;

Hence,

OEE = (ICT × GC)/PPT = (0.75 × 324)/540 = 0.45 = 45%.

4.3.2. Proposed OEE

Proposed OEE refers to the OEE that will be achieved in the proposed layout with the optimum batch size of 40 pieces.

Actual Cycle time = Processing time with allowance + TT + WT
= (50.82 + 10.16 + 12.72) second
= 73.7/60 min
= 1.23 min.

Hence, Time saving = (1.33 min – 1.23 min) × 340
= 34 min.

Number of extra bag = 34/1.23 = 28.

Total bag = 340 + 28 = 368.

With reference to existing quality, Good bag = (324/340) × 368 = 351.

Table 6. Ideal cycle time.

Sl. No.	PROCESS	ICT (Sec.)
1	Joining Logo part with Front part (INPUT)	15.00
2	Front part Lining	42.00
3	Front part Piping	45.00
4	Zipper joint with Front part	20.00
5	Side toton Stitching (INPUT)	12.00
6	Side toton piping	22.00
7	Joining Side toton with Front part	28.00
8	Handle joining and Lining Front part	45.00
9	Front part Piping	48.00
10	Top part Lining (INPUT)	19.00
11	Top part Piping	22.00
12	U-part Lining (INPUT)	25.00
13	Zipper Joint with U-part	37.00
14	Top and U-part joining through Zipper	37.00
15	Binding Top part	25.00
16	Looping Top part	8.00
17	Trolley cover Lining and Zipper joining	58.00
18	Handle joining with Gadget part (Bottom part) (INPUT)	18.00
19	Lining Bottom part	25.00
20	Two needle on Top and Bottom part (Gadget part)	72.00
21	Handle Joining with Back part (INPUT)	20.00
22	Back part Lining	75.00
23	Back part Piping	40.00
24	Joining Gadget and Back part	25.00
25	Add Front part with Combined part	45.00
26	Binding	20.00
27	Cutting Excess String	60.00
	Total Processing Time	908.00
	Adjustments	307.00
	Total time	1215.00
	Ideal cycle time per bag (sec)	45.00
	Ideal cycle time per bag (min)	0.75

The proposed layout will improve only performance factor of OEE. Other two factors are at a level in existing OEE that's why the authors focused on the performance factor.

Performance = (ICT × TC)/RT = (0.75 × 368/450) = 0.6133.

Performance increased = 0.6133 − 0.5667 = 0.0466 = 4.66%.

Hence,

OEE = (ICT × GC)/PPT= (0.75 × 351)/540 = 0.4875 = 48.75%.

OEE increased = 0.4875 − 0.45 = 0.0375 = 3.75%.

5. Result and Discussion

Proposed Layout reduced transportation time of most of the processes which is shown in Figure 4.

For some processes transportation time is higher in proposed layout but overall transportation time per batch is successfully reduced through proposed layout.

Transportation time reduced per batch = [(588 − 406)/588] × 100% = 30.95%.

Hence, the efficacy of the proposed layout is proved on the basis of transportation time per batch.

Combined effect of proposed layout and optimum batch size (40 pieces) results in 4.66% increment in performance and 3.75% increment in Overall Equipment Effectiveness (OEE).

Though proposed OEE is 3.75% higher than existing OEE it is far below as compared to the world class OEE (85%). Hence, there remains huge scope for further improvement.

Significance of this tiny improvement can be understood by quantifying the production increment per year in line 2.

Number of bag per year (Existing) = 324 bag/day × 6 day/week × 52 week/year = 101,088 bag/year.

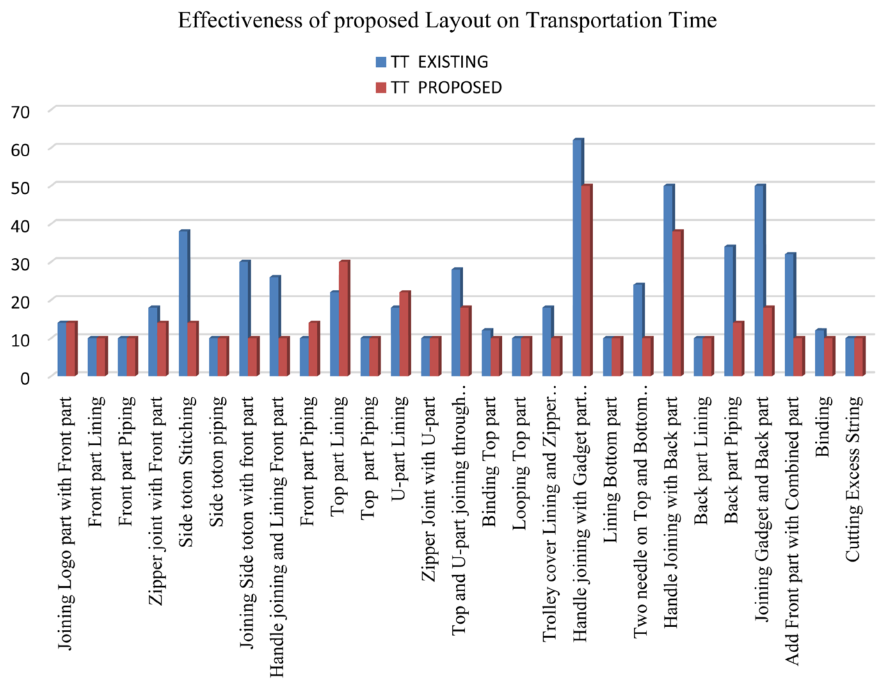

Figure 4. Comparison of transportation time for each process.

Number of bag per year (Proposed) = 351 bag/day × 6 day/week × 52 week/year = 109,512 bag/year.

Hence, Production Increment = 109,512 − 101,088 = 8424 bag/year.

6. Conclusions

Lean manufacturing principles have been implemented in different industries for several years, but few implementations are found in the sewing industry. In this research, a lean manufacturing implementation was successfully instituted in a sewing line with limited previous knowledge of lean systems. For improving productivity in the sewing line, the existing processes and layout was studied to mark out the problems and resolve them. From the study, it was found that elimination of backflow and trade-offs between waiting time and transportation time can be simple steps towards productivity improvement. A layout is proposed eliminating backflows and rearranging the processes, which leads to reduction in transportation time by 30.95%. Waiting time was another important factor, reducing which productivity could be improved. For that, a batch size is proposed through some calculation having lowest summation of waiting and transportation time. The redesigned layout and optimum batch size of 40 pieces lead to reduction in work in process inventory, waiting time and transportation time, which ultimately ameliorated Overall Equipment Effectiveness (OEE) by 3.75%. To keep track in improvement measuring and monitoring are important. For this, OEE is suggested as a powerful metric for Key Performance Indicator (KPI) which has become one of the most important industry standards to measure and monitor the effectiveness.

Lean manufacturing is an appropriate strategy to consider for improving process without high investment in machining, technology, or human training. Results of this project give some evidence of the applicability of lean manufacturing techniques in a labor-based industry, such as the sewing industry.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Womack, J. and Jones, T. (2003) Lean Thinking: Banish Waste and Create Wealth in Your Corporation. Free Press, New York.

[2] Svensson, G. (2001) Just-in-Time: The Reincarnation of Past Theory and Practice. *Management Decision*, **39**, 866-879. https://doi.org/10.1108/EUM0000000006526

[3] Rahman, M.H. and Al Amin, M. (2016) An Empirical Analysis of the Effective Factors of the Production Efficiency in the Garments Sector of Bangladesh. *European Journal of Advances in Engineering and Technology*, **3**, 30-36.

[4] Talapatra, S. and Rahman, M.H. (2016) Safety Awareness and Worker's Health Hazards in the Garments Sector of Bangladesh. *European Journal of Advances in Engineering and Technology*, **3**, 44-49.

[5] Abdulmalek, F. and Rajgopal, J. (2007) Analyzing the Benifits of Lean Manufacturing and Value Stream Mapping via Simulation: A Process Sector Case Study. *International Journal of Production Economics*, **107**, 223-236. https://doi.org/10.1016/j.ijpe.2006.09.009

[6] Hopp, W. and Spearman, M. (2000) Factory Physics Foundations of Manufacturing Management. Irwin/McGraw-Hill, Singapore.

[7] Talapatra, S., Uddin, M.K. and Rahman, M.H. (2018) Development of an Implementation Framework for Integrated Management System Based on the Philosophy of Total Quality Management. *American Journal of Industrial and Business Management*, **8**, 1507-1516. https://doi.org/10.4236/ajibm.2018.86101

[8] Rajenthirakumar, D. and Thyla, P. (2011) Transformation to Lean Manufacturing by an Automotive Component Manufacturing Company. *International Journal of Lean Thinking*, **2**, 1-13.

[9] Holweg, M. (2007) The Genealogy of Lean Production. *Journal of Operations Management*, **25**, 420-437. https://doi.org/10.1016/j.jom.2006.04.001

[10] Taj, S. and Berro, L. (2006) Application of Constrained Management and Lean Manufacturing in Developing Best Practices for Productivity Improvement in an Auto-Assembly Plant. *International Journal of Productivity and Performance Management*, **55**, 332-345. https://doi.org/10.1108/17410400610653264

[11] Shaeffer, C. (2000) Sewing for the Apparel Industry. Prentice Hall, Upper Saddle River, NJ.

[12] Hodge, G., Ross, K., Joines, J. and Thoney, K. (2011) Adapting Lean Manufacturing Principles to the Textile Industry. *Production Planning & Control*, **22**, 237-247. https://doi.org/10.1080/09537287.2010.498577

[13] Achanga, P. and Shehab, E. (2006) Critical Success Factors for Lean Implementation within SMEs. *Journal of Manufacturing Technology Management*, **17**, 460-471. https://doi.org/10.1108/17410380610662889

[14] Womack, J.P., Jones, D.T. and Ross, D. (1990) The Machine That Changed the World. Macmillan, New York, NY.

[15] MacDufile, J.P. and Helper, S. (1997) Creating Lean Suppliers: Diffusing Lean Production through the Supply Chain. International Motor Vehicle Program (IMVP), FY'97 IMVP Working Papers.

[16] Brintrup, A., Ranasinghe, D. and McFarlane, D. (2010) RFID Opportunity Analysis for Leaner Manufacturing. *International Journal of Production Research*, **48**, 2745-2764. https://doi.org/10.1080/00207540903156517

[17] Shah, R. and Ward, P.T. (2007) Defining and Developing Measures of Lean Production. *Journal of Operations Management*, **25**, 785-805. https://doi.org/10.1016/j.jom.2007.01.019

[18] Hopp, W.J. and Spearman, M.L. (2004) To Pull or Not to Pull: What Is the Question? *Manufacturing & Service Operations Management*, **6**, 133-148. https://doi.org/10.1287/msom.1030.0028

[19] Rother, M. and Shook, J. (1999) Learning to See—Value Stream Mapping to Create Value and Eliminate Muda. Version 1.2, The Lean Enterprise Institute Brookline, Brookline.

[20] Marvel, J.H. and Standridge, C.R. (2009) A Simulation-Enhanced Lean Design Process. *Journal of Industrial Engineering & Management*, **2**, 90-113.

[21] Shah, R. and Ward, P.T. (2003) Lean Manufacturing: Context, Practice Bundles, and Performance. *Journal of Operations Management*, **21**, 129-149.

https://doi.org/10.1016/S0272-6963(02)00108-0

[22] Anvari, A.R., Norzima, Z., Rosnay, M.Y., Hojjati, M.S.H. and Ismail, Y. (2010) A Comparative Study on Journey of Lean Manufacturing Implementation. *AIJSTPME*, **3**, 77-85.

[23] Wu, S. and Wee, H.M. (2009) How Lean Supply Chain Effects Product Cost and Quality—A Case Study of the Ford Motor Company.

[24] Parry, G. and Mills, J. (2010) Lean Competence: Integration of Theories in Operations Management Practice. *Supply Chain Management: An International Journal*, **15**, 216-226. https://doi.org/10.1108/13598541011039974

[25] Tiwari, A., Turner, C. and Sackett, P. (2007) A Framework for Implementing Cost and Quality Practices within Manufacturing. *Journal of Manufacturing Technology Management*, **18**, 731-760. https://doi.org/10.1108/17410380710763886

[26] Wacker, J.G. (1998) A Definition of Theory: Research Guidelines for Different Theory-Building Research Methods in Operations Management. *Journal of Operations Management*, **16**, 361-385. https://doi.org/10.1016/S0272-6963(98)00019-9

[27] Liker, J.K. (1996) Becoming Lean. Free Press, New York.

[28] Womack, J.P. and Jones, D.T. (1994) From Lean Production to the Lean Enterprise. *Harvard Business Review*, **72**, 93-103.

[29] Wan, H.-D., Chen, F.F. and Rivera, L. (2007) Leanness Score of Value Stream Maps. *Proceedings of the* 2007 *Industrial Engineering Research Conference*.

[30] Kuhlang, P., Edtmayr, T. and Sihn, W. (2011) Methodical Approach to Increase Productivity and Reduce Lead Time in Assembly and Production-Logistic Processes. *CIRP Journal of Manufacturing Science and Technology*, **4**. https://doi.org/10.1016/j.cirpj.2011.02.001

[31] Fullerton, R.R. and Wempe, W.F. (2009) Lean Manufacturing, Non-Financial Performance Measures, and Financial Performance. *International Journal of Operations & Production Management*, **29**, 214-240. https://doi.org/10.1108/01443570910938970

[32] Agus, A. and Hajinoor, M.S. (2012) Lean Production Supply Chain Management as Driver towards Enhancing Product Quality and Business Performance. *International Journal of Quality & Reliability Management*, **29**, 92-121. https://doi.org/10.1108/02656711211190891

[33] Wan, H.-D. and Chen, F.F. (2008) A Leanness Measure of Manufacturing Systems for Quantifying Impacts of Lean Initiatives. *International Journal of Production Research*, **46**, 6567-6584. https://doi.org/10.1080/00207540802230058

[34] Hon, K.K.B. (2003) Performance and Evaluation of Manufacturing Systems. Department of Engineering, University of Liverpool, Liverpool.

[35] Karlsson, C. and Ahlstrom, P. (1996) Assessing Changes towards Lean Production. *International Journal of Operations & Production Management*, **16**, 24-41. https://doi.org/10.1108/01443579610109820

[36] Wan, H.-D. and Chen, F.F. (2009) Decision Support for Lean Practitioners: A Web-Based Adaptive Assessment Approach. *Computers in Industry*, **60**, 277-283. https://doi.org/10.1016/j.compind.2009.01.001

[37] Bayou, M.E. and de Korvin, A. (2008) Measuring the Leanness of Manufacturing Systems: A Case Study of Ford Motor Company and General Motors. *Journal of Engineering & Technology Management*, **25**, 287-304. https://doi.org/10.1016/j.jengtecman.2008.10.003

[38] Behrouzi, F. and Wong, K.Y. (2011) Lean Performance Evaluation of Manufactur-

ing Systems: A Dynamic and Innovative Approach. *Procedia Computer Science*, **3**, 388-395. https://doi.org/10.1016/j.procs.2010.12.065

[39] Wong, B.K. and Lai, V.S. (2011) A Survey of the Application of Fuzzy Set Theory in Production and Operations Management: 1998-2009. *International Journal of Production Economics*, **129**, 157-168. https://doi.org/10.1016/j.ijpe.2010.09.013