DEPLOYMENT OF PDCA BY INTEGRATING LEAN MANUFACTURING TOOLS

R. Azzemou and M. Noureddine

Faculty of Mathematics and Computer Science,
University of Science and Technology of Oran Mohamed Boudiaf,
1505 El M'Naouer, 31000 Oran, Algeria.

Corresponding Author’s Email: rabea.azzemou@univ-usto.dz

Article History: Received 4 June 2020; Revised 30 April 2021;
Accepted 16 August 2021

ABSTRACT: The current framework of economic competition requires the firms to have growing productivity and optimizing management of firm flows. In this context, this article proposes a quality approach in the "KAIZEN" spirit, by way of a PDCA deployment. The PDCA promotes continuous improvement of processes and allows constantly enhance quality in an organization. The adopted methodology integrates a Lean Manufacturing tool at each stage of the PDCA cycle. Approach is applied on a local SME specializing in leather goods and performance measures are introduced through specific indicators, grouped into process indicators for efficiency and effectiveness and flow indicators for delivery time and flow tension index. The end results enhance these measures, demonstrating the relevance of using Lean tools in the PDCA cycle. This study gives a plat-form to improve flow management by reducing operations that provide non-added value to the company.

KEYWORDS: *Quality; Kaizen; PDCA; Performance; Indicator*

1.0 INTRODUCTION

Globalization, opening of markets, development of information and communication technologies forces companies to be more productive and competitive. One of key factors for increasing productivity and improving deadlines is control of physical flows and the fluidity of information flows. These monitoring contributes to performance improvement and in this context, company must have indicators to identify necessary actions for enhancing its performance and to make decisions based on obtained results. A successful company [1-3] must be both effective when it achieves objectives it has set and efficient when it minimizes used resources for reaching their goals. Thus, effectiveness and efficiency measures make it possible to assess whether implementation of an action or a process produces exactly expected results with provided means; on the other hand, measurement of the flows allows better reactivity with an adapted and reliable organization of the concerned enterprise.

In background of increasing performance, the problem is how to enhance management of flows. The article objective is to answer this problematic by proposing a quality approach in the "KAIZEN" spirit to improve management of the flows in a company. In this framework, a PDCA deployment is proposed with integration of Lean Manufacturing tools according to the four steps of the PDCA (Plan, Do, Check, Act). The proposed approach is applied to a local SME specializing in leather goods. Internal logistics of its production comes up against organizational difficulties mainly due to reduction of its workforce (50%) and information system put in place. The implementation approach will attempt generating an effective and efficient internal logistics management and optimizing flows. Final results give an improvement in its production following a reduction in operations that do not generate added value for the company.

In a second section, quality management is presented according to KAIZEN approach. The third section is dedicated to integrating Lean into the PDCA method. In fourth section, the approach is validating through deployment of the PDCA within leather goods manufacturing company, detailing all steps and interpreting obtained results.

2.0 QUALITY MANAGEMENT

2.1 Kaizen Approach

Kaizen is at heart of Lean Manufacturing and aims to continuously improve processes, eliminating waste, improving workstations and optimizing productivity [4]. This concept retains that continuous improvement requires involvement of all actors in order to deploy concrete improvement processes, simple and inexpensive, and carried out in a short period of time [5]. The Kaizen dynamic consists of continuously making improvements initiated by users as part of fight against waste bringing no added value. Kaizen is a state of mind based on principles and not a tool [6]. It is about anticipating and acting while seeking to continuously improve working methods and procedures without any investment. Malfunctions are corrected as soon as they appear by involving all employees and comparing their view points in order to help the collective decision-making process. These principles are leverage experience and creativity of all staff, search for durable solutions by detecting waste sources, reconfiguration of equipment layout and personnel to make the best use of space and improve productivity and PDCA cycle monitoring.

2.2 Performance Measures

Performance defines as a result achievement in accordance with consistent objective with the business purpose previously defined and measurable. Performance is largely based on the effectiveness and efficiency notions [7]. Performance measurement is a lever for creating value because it allows an evaluation of effectiveness and efficiency of actions carried out by the organization [8]. Therefore, the most used performance indicators are effectiveness, efficiency, lead time and flow tension index.

i. Effectiveness (ESS) could be defined as "the capacity to achieve objectives" [9]. It's consists in making good services or good products. Effectiveness indicator ESS is calculated by

$$\mathrm{ESS} = \frac{\text{Number of steps at Added Value (AV)}}{\text{Number of steps AV + Non - Added Value (NAV)}} \tag{1}$$

ii. Efficiency (EFF) is art of improving productivity, adapting processes and eliminating unnecessary tasks. Efficiency introduces optimization notion. Efficiency indicator EFF is determined by

$$\mathrm{EFF} = \frac{\sum \mathrm{AV}(\mathrm{time})}{\mathrm{LT}} \tag{2}$$

iii. Lead time (LT) or crossing time is a key element of productivity. This indicator measures responsiveness of logistics for customers [10]. It is calculated as follows:

$$\mathrm{LT} = \sum \mathrm{AV}(\mathrm{time}) + \sum \mathrm{NAV}(\mathrm{time}) \tag{3}$$

iv. Flow tension index (FTI) is an indicator that allows assessing whether the physical flow is tense or not and therefore to know if the flow time is used effectively. Flow tension index, FTI is calculated as follows:

$$FTI = \frac{1}{EFF} \tag{4}$$

3.0 QUALITY TOOLS IN PDCA APPROACH

3.1 Methodology

Deming wheel (PDCA) is the graphic representation of a quality management method [11]. Its implementation should make it possible to improve consistently the quality of a product, a service or an organization. The quality consist of four steps cyclic process, known as PDCA namely, Plan, Do, Check, and Act.

i. Plan: This first step will allow plan, analyze and understand real causes of the problem.
ii. Do: The second step is to identify solutions and design these solutions.
iii. Check: The third step is a check step by verifying solutions, measuring, improving and evaluating results.
iv. Act: This fourth step concerns implementation of generalized solution and starting another cycle.

Within the continuous improvement framework, the last step ("Act") automatically leads to the first step ("Plan"). Our approach consists to deploy the Deming wheel by using a tool from Lean Manufacturing for each step of the PDCA, as shown in Figure 1.

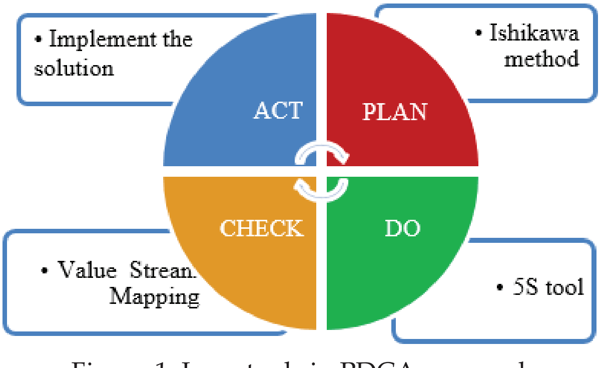

Figure 1: Lean tools in PDCA approach

In any continuous improvement process, it is necessary and essential to make a precise inventory of manufacturing process flows. Thus, as a preliminary step of the PDCA application, current state of the different flows is mapped and analyzed.

Quality tools apply to all environments and facilitate transformation actions of the company. Among these tools [12-13], we adopt Ishikawa diagram which remains the best known and most used quality tool, 5S which are basic rules of order and discipline, Value Stream Mapping (VSM), which is an analysis method of production flow.

3.2 Ishikawa Method for Plan Step

In PDCA process, the first step "Plan" is very important as it is about planning, meaning achieving, defining priorities, objectives, action plan. In this context, identification of dysfunctions is fundamental and Ishikawa diagram [14] or 5M diagram is an excellent communication tool to explain a phenomenon and plan implementation of corrective actions. It is a graphical tool which is used to understand causes of a quality defect and to analyze the relationship between a problem and all possible causes. The causes are classified according to five families: manpower, mother-nature (environment), method, material and mean. Each cause family receives other causes depending on level of importance or detail.

3.3 5S Tool for Develop Step

The "Develop" step consists in developing, carrying out the comparative test or the experiment, applying defined action plan in the first step (Plan) by implementing all corrective operations. The selected tool is the 5S (Seiri, Seiton, Seiso, Seiketsu and Shitsuke) is the first tool to be implemented in a Lean Manufacturing approach; it has for main objective of setting a continuous improvement policy. The 5S such as in [15] makes it possible to eliminate what is unnecessary (Seiri), define a place for everything (Seiton), clean up (Seiso), define necessary ranges and procedures (Seiketsu) and finally audit and measure the improvement (Shitsuke). It allows better control of environment on the ground [16]. The application of 5S makes it possible to build solid foundations for a Lean Manufacturing approach [17].

3.4 VSM for the Control and Action Steps

The third step "Control" allows control implemented resources in the previous step (Develop) and see if obtained results correspond to what was planned (Plan). The last "Act" step in the cycle consists of adjusting deviations, checking effectiveness of implemented solutions over time and looking for improvement points until the expected level is reached.

For these two steps, the adopted tool is Value Stream Mapping (VSM), a visual Lean Manufacturing tool allowing a descriptive mapping of flows. The idea consists in monitoring a product throughout the process, noting all reliable information such as performed tasks, cycle times, waiting times, lead times, quality and non-quality rates. The VSM confers an advantage both at level of the organization itself and in activities occurring along the manufacturing process [18-19]. Thus, by applying VSM for modeling of flows through mapping of current and future states, control and verification of the effectiveness of implemented solutions will be done and all activities will increase their efficiency.

4.0 CASE STUDY

4.1 Company Specification

The concerned company is a Limited Liability Company (LLC) which manufactures and markets leather goods (school bags, belts, Travel bags and suitcases). Its activity field covers the entire national territory through its distribution network. To ensure production of articles in natural and synthetic leather, this company uses a wide range of imported raw materials and accessories. The manufacturing process is the same for all manufactured products that pass through same equipment undergoing same treatment before being packaged and shipped. The organization is based on circulation of material and information flows between the different workstations spread over three levels, with exchange of products on these levels.

i. First level: Store of raw materials is located at the level where the "cutting" operation of leather, cardboard and fabric takes place. Cut pieces are routed to the first floor (below grade).
ii. Second level: The accessories store is installed on this level for bonding, mounting and stitching operations. Semi-finished products are transported to first level for further processing.

iii. Third level: The store for finished products is located where the "finishing" operation is carried out. Finished product is transferred to the first level for quality control.

The overall strategic diagnosis as part of upgrading program from which this company benefited in 2000 recommended actions in commercial field, purchasing field and production field. Although company was certified ISO 9000, currently after the diagnosis, the enterprise is facing with various organizational problems and suffers a lack of staff (reduction of the workforce by 50%). Thus, organization and operation of the workshops have become permanent challenges that have led the company to rethink its layout and plan the circulation of physical and information flows. In this aim, proposed approach is applied. Control of the physical flows and flow of information; at operational level is essential in the company with the objective is to visualize the existing situation in terms of flows and deadlines for identifying failures within the company as shown in Figure 2.

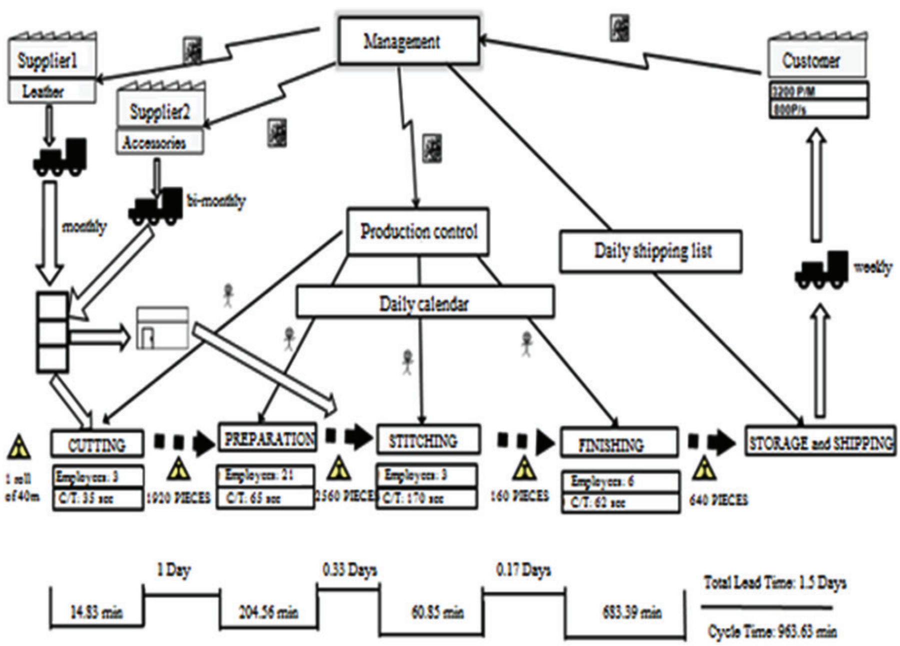

Figure 2: VSM of current state

The VSM analysis is a part of the manufacturing cycle covers the entire process (bottleneck): the “Finishing” step is the part with lowest rate in the flow of production process having 71% of the cycle time. Thus, the two creation times of non-added and added values are almost the same with 437.62 min for non-added value and 526.01 min for added value. Furthermore, observation of manufacturing flows revealed other dysfunctions linked to the follower sheet filled in irregularly or incompletely due to attention lack and to the high rate of "Turn-Over" of workers.

4.2 PDCA Deployment

Following the adopted approach, in the Plan step, Ishikawa method allowed identifying the dysfunctions; then in Do step, 5S tool is used by proposing corrective actions. Consider the 4 M: method, mother-nature (environment), manpower and material. For each axis M, identify the dysfunctions within the company and give corresponding corrective actions, as shown in Table 1.

Table 1: Dysfunctions and corrective actions

Ishikawa method		5S					Correctives actions
Axis	Dysfunctions	1	2	3	4	5	
Method	Lack of maintenance manuals				X	X	- Revision of tracking sheet (Computerization) - Implementation of - procedures - self-maintenance - self-monitoring - standards - Reorganization of workshops - Organization of working hours - Control waste quantities and flow
	Follower not adapted				X	X	
	Faulty maintenance	X	X	X	X	X	
	Poor evacuation of parts	X	X	X	X	X	
	Poor organization of storage	X	X	X	X	X	
	No planning				X	X	
	Anarchic distribution of tissue rolls in the workshop	X	X	X	X	X	
	Downstream quality control	X	X	X	X	X	
	Significant drop rate of raw materials	X	X	X	X	X	
Mother-nature (Environment)	Inadequate location of machines	X	X	X	X	X	- Put in a maintenance program - Installation of a ventilation system - Wearing suitable masks and working clothes - Marking of zones
	Workshop insalubrities	X	X	X	X	X	
	Dirty and full trash cans	X	X	X	X	X	
	Indoor air pollution	X	X	X	X	X	
	Cluttered workstation	X	X	X	X	X	
	High dust content	X	X	X	X	X	
Manpower	Bad internal communication				X	X	- Sharing and circulation of information - Worker awareness and training - Work reorganization
	Inattention errors				X	X	
	High turn-over				X	X	
	unnecessary movement				X	X	
Material	Recurring machine failures	X	X	X	X	X	- Implementation of self-maintenance
	No maintenance, no monitoring system	X	X	X	X	X	

5S Method: 1: Seiri, 2: Seiton, 3: Seiso, 4: Seiketsu and 5: Shitsuke

Figure 3 shows the future state mapping through the VSM method. For each level of the process, the quality control (QC) is added. This will allow errors to be detected from the start, with significantly reduce costs compared to the final inspection and the computerized process is applied for the tracking sheet, which will save time with fewer errors. Thereby, a wide difference appeared between time of non-added value with 162.87 min and added value time with 456.31 min.

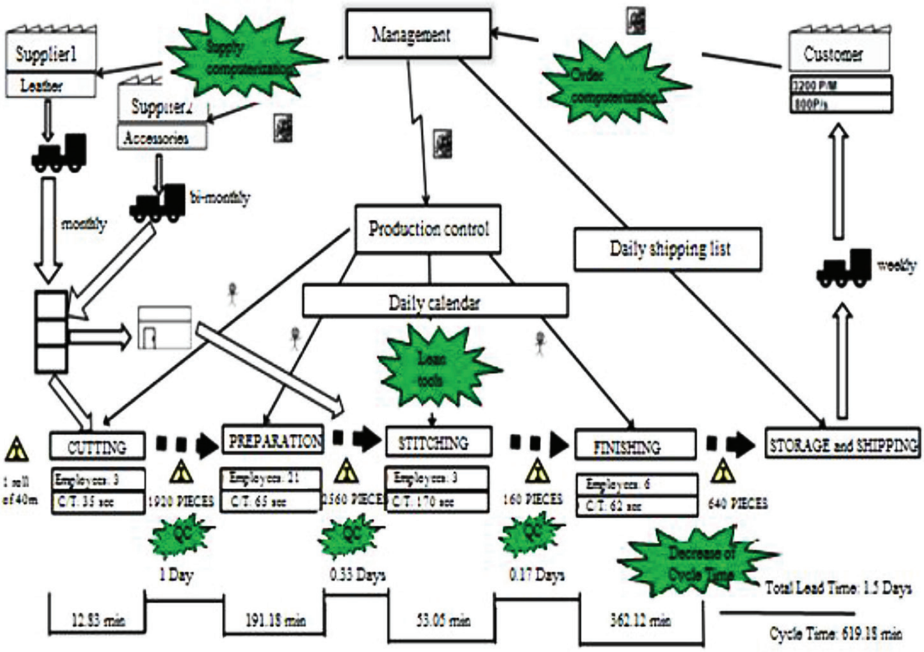

Figure 3: VSM of future state

4.3 Results and Interpretation

Following the given reduction in staff and financial means to invest in purchase of new machines, lasting improvements are possible thanks to the formalization, verification and reorganization of the company. Thus, reorganizing the business consists of aiming process indicators and indicators of flows. Analysis of obtained cartography for current state and future state made it possible to have measurements of adopted performance indicators. These measures are grouped into two classes: the first one is relating to process indicators with effectiveness (ESS) and efficiency (EFF). The second one gives evaluation of flows with lead time (LT) and flow tension index (FTI). Following equations as mentioned above, the obtained results on the two cartographies are shown in Table 2.

Table 2: Measures of performance indicators

Performance measures	Indicators			
	Process		Flows	
	ESS	EFF	LT	FTI
Before optimization	0.42	0.55	963.63	1.82
After optimization	0.37	0.74	619.18	1.35

View of results reveals a decrease by 11.90% of effectiveness indicator. This is explained by introduction of quality control upstream of preparation steps located on the first level and final steps located on the second level. After benchmarking with the company managers, the result is validated as the company seeks to manufacture a quality product. Following estimation of added-value and non-added value, process efficiency increased by 34.54% due to implementation of a computerized tracking sheet replacing the paper tracking sheet, which no longer met production needs. This has ensured traceability, better organization of work, a history of all operations and avoided errors throughout the manufacturing process.

Crossing time has decreased by 35.74%. Reduction of crossing time supposes the control of supply and internal flows as well as the delivery flow. It is a strategic indicator for positioning company in relation to market and this will contribute to improving its competitiveness. The flow tension index went from 1.82 to 1.35 that is a decrease in the flow tension index by 25.82% indicates that the identified bottleneck has been removed. This result is due to establishment of new organization through tracking sheet computerization. Each operation is quickly identifiable, with fewer errors and therefore loss of time.

5.0 CONCLUSION

The approach consists of integrating Lean Manufacturing tools between PDCA and "KAIZEN” is presented. Kaizen is at heart of Lean Manufacturing and aims to improve processes continuously, eliminating waste, improving workstations and optimizing productivity. The approach is applied to a local SME specializing in leather goods having encountered many problems with its external environment and its current organization called into question. According to the proposed approach, we were interested in production flow and restructuring of the company in order to adapt a new organization. First in a preliminary step, we modelled physical and information flows using the VSM for current state; then considering the first step of the Deming Wheel (Plan), malfunctions are identified using Ishikawa method. In the second step (Do), we applied the 5S tool to identified dysfunctions. This led to generation of a set of corrective actions that will improve the functional and organizational processes of the company and the wasteful elimination of non-added value tasks. The third step (Check & Act) consisted in controlling implemented resources (corrective actions) and obtained results (VSM future state).

For a validation of the approach, the company performance is evaluated through indicators such as effectiveness, efficiency, lead time and flow tension index. These measures are done before and after implemented solutions, giving time improvements. Thus, obtained results indicate that effectiveness indicator decreases as the company opted for a quality product by introducing quality control upstream. The efficiency indicator increased by cause of corrective actions to bring better organization of work due to computerization of the tracking sheet. It also reduced crossing time and flow tension index, thus revealing the removal of the identified bottleneck. The enhancement of the measures demonstrates the relevance of using specific Lean tools in the PDCA cycle. The adopted methodology focuses on quality tools through analysis and mapping production flow, identification of dysfunctions and implementations of corrective operations. This study allows defining a first plat-form to improve both production flow management and operators' working conditions by propositions of corrective actions. For illustration, a ventilation system installation, the wearing suitable masks and working clothes will contribute to a better working environment.

In future study, the proposed framework is expected to develop in order to implement other tools in particular for corrective actions as example Total Productive Maintenance to put a maintenance program, Kanban system to mark zones, Just in Time to control production without wastes. This article is the basis of a development of a platform dedicated to continuous improvement of processes with social, environmental and economic benefits.

ACKNOWLEDGEMENTS

The authors thank all the reviewers for their remarks and suggestions.

REFERENCES

[1] H. Hamadmad, "Définition d’une expression temporelle de la performance des entreprises manufacturières", Thèse de doctorat, Grenoble Alpes University, France, 2017.

[2] A. W. Dametew and F. Ebinger, "Performance analysis of manufacturing industries for system improvement", *Industrial Engineering & Management*, vol. 6, no. 228, pp. 2169-0316, 2017.

[3] J. Trojanowska, A. Kolinski, D. Galusik, M. L. R. Varela and J. Machado, "A methodology of improvement of manufacturing productivity through increasing operational efficiency of the production process", in *Advances in Manufacturing*, A. Hamrol, O. Ciszak, S. Legutko and M. Jurczyk. New York: Springer, 2018, pp. 23-32.

[4] I. Masaaki, *Kaizen: The key to Japan's competitive success.* New York: McGraw-Hill, 1986.

[5] K. Otsuka, K. Jin and T. Sonobe, *Applying the kaizen in Africa: A new avenue for industrial development*. Berlin: Springer Nature, 2018.

[6] S. Harvey, *Kaizen: The Japanese secret to lasting change—small steps to big goals.* New York: The Experiment, 2020.

[7] O. Uygun and A. Dede, "Performance evaluation of green supply chain management using integrated fuzzy multi-criteria decision making techniques", *Computers & Industrial Engineering,* vol. 102, pp. 502-511, 2016.

[8] L. Ashdown, *Performance management: A practical introduction*. London: Kogan Page Publishers, 2018.

[9] C. Maurel and M. Tensaout, "A model of representation and evaluation of the global performance", *Accounting Auditing Control*, vol. 20, no. 3, pp. 73-99, 2014.

[10] P. Drucker, *The effective executive*. Oxfordshire, UK: Routledge, 2018.

[11] M. Jagusiak-Kocik, "PDCA cycle as a part of continuous improvement in the production company-a case study", *Production Engineering Archives*, vol. 14, pp. 19-22, 2017.

[12] M. Sokovic, D. Pavletic and K. K. Pipan, "Quality improvement methodologies–PDCA cycle, RADAR matrix, DMAIC and DFSS", *Journal of Achievements in Materials and Manufacturing Engineering*, vol. 43, no. 1, pp. 476-483, 2010.

[13] S. F. Fam, N. Ismail, H. Yanto, D. D. Prastyo and B. P. Lau, "Lean manufacturing and overall equipment efficiency (OEE) in paper manufacturing and paper products industry", *Journal of Advanced Manufacturing Technology,* vol. 12, no. 1(2), pp. 461-474, 2018.

[14] M. F. Suárez-Barraza and F. G. Rodríguez-González, "Cornerstone root causes through the analysis of the Ishikawa diagram, is it possible to find them?: A first research approach, *International Journal of Quality and Service Sciences,* vol. 11, no. 2, pp. 302-316, 2019.

[15] J. S. Randhawa and I. S. Ahuja, "5S–a quality improvement tool for sustainable performance: literature review and directions", *International Journal of Quality & Reliability Management*, vol. 34, no. 3, pp. 334-361, 2017.

[16] M. Adzrie F. O. Chai, K. Elcy, R. M. Joselyn, N. Mohd-Lair and M. A. Madlan., "Implementation of 5s in small and medium enterprises (SME)", *Development*, vol. 61, no. 1, pp. 1-18, 2019.

[17] R. Azzemou and M. Noureddine, "Application of the 5S method in an Algerian firm", *Management*, vol. 2, no. 5, pp. 193-203, 2012.

[18] A. K. Dhingra, S. Kumar and B. Singh, "Cost reduction and quality improvement through lean-kaizen concept using value stream map in Indian manufacturing firms", *International Journal of System Assurance Engineering and Management*, vol. 10, no. 4, pp. 792-800, 2019.

[19] D. Stadnicka and P. Litwin, "Value stream mapping and system dynamics integration for manufacturing line modelling and analysis", *International Journal of Production Economics*, vol. 208, pp. 400-411, 2019.