VOL. 17, NO. 4, FEBRUARY 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

PRODUCTIVITY IMPROVEMENT OF A GARMENT ASSEMBLY LINE USING SIMULATION AND MODEL DRIVEN DECISION SUPPORT SYSTEM

Venkata Mallikharjuna Kishan Ivatury[1] and Ketema Bobe Bonsa[2]
[1]Department of Industrial Engineering, School of Mechanical and Industrial Engineering, Institute of Technology Hachalu Hundessa Campus, Ambo University, Ambo, Ethiopia
[2]Department of Mechanical Engineering, School of Mechanical and Industrial Engineering, Institute of Technology Hachalu Hundessa Campus, Ambo University, Ambo, Ethiopia
E-Mail: Kishan.ivatury@gmail.com

ABSTRACT

The disruption caused due to the current pandemic situation in the areas of supply chains, tourism, aviation, hospitality, sports and fashion is enormous. This effect is more visible in manufacturing sector especially in fashion, appeal and garment industry. This resulted in the companies emphasizing on the effective utilization of resources and enhanced productivity. Although, the concept of lean manufacturing, value stream mapping (VSM), Jidoka, Kaizen, 5S, Kanban, Poka Yoke, line balancing and many more are available in the literature, that can enhance productivity, the incorporation of data analytics and software-based simulations as a method to support decision making in real time production activity to enhance productivity is the need of the hour. The aim of the research paper is to develop a framework of model driven decision support system (MD-DSS) where real time data is fed to the system and data simulation and communication technologies help in improving the productivity of the manufacturing process. An empirical study was conducted at AL Apparel Manufacturing PLC, Addis Ababa (Ethiopia) garment manufacturing facility to demonstrate the proposed model. Data is collected through observations, document studies, and time study measurements for skimmer trouser having 34 operations. The assembly line is balanced using discrete event Arena simulation program. The results indicated that the proposed model has high line efficiency and increased productivity.

Keywords: assembly line, decision support system, arena.

1. INTRODUCTION

Garments are an essential part of human beings' sustenance and existence. Garment industry has traditionally been the first step towards industrialization in any developing countries. The garment industry has experienced a massive growth in last four decades and continues to be the strongest manufacturing sub-sector in developing countries. The textile and garments industry is one of the largest in the world and have a major role in the economy of any country [1, 2]. In garment industries production systems are classified into mass production system and batch production system. In mass production system, manufacturing facility is geared up to produce the products of interest in large volume, whereas in batch production system, manufacturing facility is geared up to produce the products in much smaller volumes. A flow line may be used for the mass production system, which produces the same product over a long period of time. The batch production is realized through job shop implementation [3].

An assembly line consists of a set of workstations where a set of operations are carried out with the aim of obtaining the final product [4]. In assembly line, tasks are allocated to the workstations considering some restrictions including precedence constraints, cycle time, and the number of workstations, and thus increasing its complexity [5]. However, assembly lines are used extensively in mass production systems to produce high quantity standardized products [6]. Assembly lines are classified according to the number of models and products that they produce [7]. They are divided into groups according to the way they are produced. Assembly line balancing methods are separated into three groups according to the solution approach: single model, multi-model and mixed-model assembly lines [2]. Assembly line balancing method-based solution approaches are threefold: Heuristic methods, analytical methods and simulation techniques [8]. One of the most significant factors affecting the competitiveness of the garment industry which uses assembly lines is low productivity. The term "productivity" can be used to assess or measure the extent to which a certain output can be extracted from a given input [9, 10].

For this reason, assembly line balancing becomes very crucial for proper functioning of the assembly line system. The balancing of assembly lines is an important issue in manufacturing engineering, management, and control. Time standards are needed to manage a firm's production and operation effectively. Short- and long-term production planning of production, cost control and optical utilization of resources and many more depend on establishing time standards for the operations [11].

The operation, production, control and plans which are performed according to the standard time assigned by means of work measurement enable to minimize time loss and increase efficiency [12]. For these reasons, the standard time is calculated and used in every firm. Standard time is the total time for finalizing an operation along with the standard performance [13]. The time study method most widely used in companies is the stop watch technique [14].

Despite the fact that research on assembly line balancing dates back to more than a century, it is still of interest to many researchers. This is because assembly line balancing problem (ALBP) is directly related to production efficiency. Number of methods has been introduced by researchers to improve productivity in garment industries. Some techniques deal with specific problems such as inventory, quality lean manufacturing and set-up time [15, 16]. Although a garment factory consists of several departments, the sewing department is the most important department in the whole firm. Because a lot of different operations are carried out manually there by providing the scope for improvement. Line balancing is one of the techniques that can be used to enhance the productivity in production lines. Job assignment to operators in a production line by means of a scientific approach is extremely important to maintain the consistency of operating efficiency.

Simulation is a technique used to imitate the actual operations of a real system. It is used to help the decision-maker to understand the behaviour of the system and implement necessary improvements. There have been various studies conducted in various areas using simulation approaches to solve problems in the manufacturing, food processing [17], transportation, health care [18], military and other industries.

Simulation has become a widespread technique in assessing the impact of decisions made in any sector. Simulation techniques presently are widely used in combination with operation research and artificial intelligence approaches in helping the decision-maker to identify the problems in the system and evaluate various alternatives for system improvements before making decisions.

In the manufacturing industry, simulation has been widely used to solve many problems such as resource planning, worker scheduling, material handling process, performance improvements, and others. Production enhanced scheduling procedures using a simulation approach in pharmaceutical companies with large product mixes [19]. They assessed the performance of a schedule by measuring resource utilization, identifying bottlenecks, throughput, and evaluating the impact of each item in the product mix. Simulation approaches were also used in workforce scheduling used the discrete event simulation (DES) model in planning a job-shop environment by using Arena simulation software [20].

Simulation is a scientific method to separately study a system without actually disconcerting it, but also to assess ideas that have not been used in the real world [21]. Simulation is used to predict assembly line performance among other machine layouts and scheduling rules, thus find the best performing layout. Simulation modelling is mostly used to support decision-making in various commercial tasks [22]. The model simulations offer data about the process results, performance and behaviour with diverse process structures [23]. Manufacturing simulation approach is a set of manufacturing policies planned to maximize performance among trade-offs among profit standards to meet the manufacturing job determined by a corporate strategy [23].

This research paper focuses on using simulation method as a method to improve the line efficiency in a garment factories considering real time data collected at work stations.

2. RESEARCH METHOD

To compete with growing international demand, smart productions are needed. They are facilitated by integrating the physical work environment and virtual worlds [24]. The virtual environments can be developed to replicate the real environments by simulation methods. The integration is done by manual/automatic and offline/online data collection and feeding to the systems. For this, internet networking concept, sensors are used to capture the data. Data is installing into the database at the machine before transmitting to server through intranet. By using MySQL commands, these data are compiled and coding to align the simulation requirement inputs. This is the main basic of networking system towards Industry 4.0. By doing so, all physical devices can be connected to the Internet. The proposed model driven decision support system (MD-DSS) provide a compressive and effective framework on how assembly line data can be simulated for proper decision making is illustrated in Figure-1.

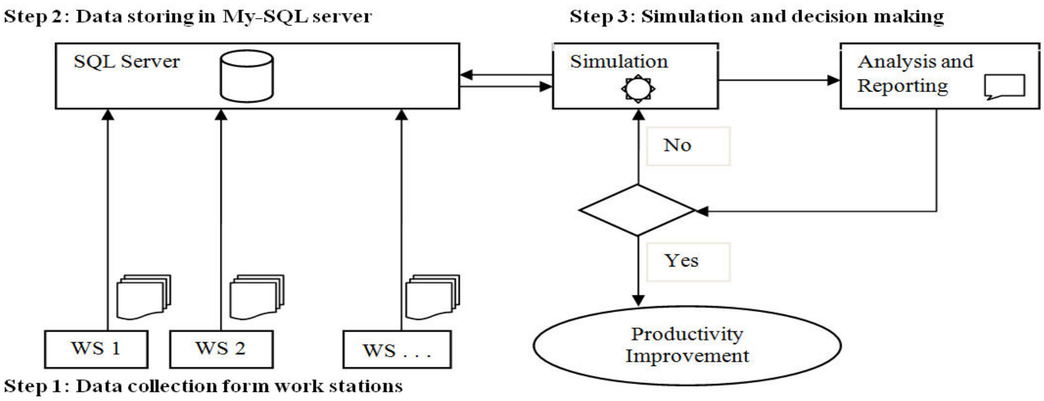

Figure-1. Proposed model driven decision support system (MD-DSS) framework.

VOL. 17, NO. 4, FEBRUARY 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Step 1: Collecting Data: Data is gathered through conducting time study measurements. Data collection methods used is physical observations, document studies, and time study measurements with the help of sensors placed on the sewing machines. 30 readings for every operation/task were taken over a period of 3 days. In this study, data were collected using a web-based program, where PHP language, web-based database MySQL, and web serve provider Linux are used. The PHP + MySQL platform is a famous database-driven web service that facilitates the proposed framework. The sensors at the machines are used to collect data processes. A set of data retrieved by sensors before transmitted to MySQL database. With the help of intranet and SQL command, all required data from selected machines are compiled into database MySQL.

Step 2: Storing Data: Compiled data at database MySQL were aligned based on the simulation input such as cycle time, number of machine/work stations, target quantity, number of operators etc. A simulation model is used to simulate the production system to figure out the real operation of the garment assembly system in the production line.

Step 3: Simulation and Decision Making: Simulation is a very helpful tool to assist in the decision-making process to implement smart production concepts related to Industry 4.0 at the existing assembly operation [25, 26]. Models are developed similar with the existing production system. In addition to the garment assembly processes, the related elements such us waiting times, lot sizes, minimum inventory quantity requirements, transportation times, standard times and precedence constraints are included in the model to enable the feel of real assembly line.

In this research, to demonstrate the MD-DSS, discrete event simulation (DES) is used. This is a powerful tool to support organizations with the decision to implement lean manufacturing by counting the benefit based on the specific situation [27]. Before decision making, DES model created to estimate the system capability for the optimal settings of decision variables. The decision makers define the decision variables or scenarios which can be changed based on their allowable ranges.

The computer model of the skimmer trouser assembly line was developed based on DES using Arena simulation software (Academic License Version 14). The simulation model was built on a 64 bits ThinkPad computer with a 3.00 GHz Intel core i7 CPU and 16.00 GB RAM. Although the processing speed of the think pad computer is high, 32 bits Arena software category was well-suited to be installed instead of the 64 bits. Consequently, the simulation model was developed and run smoothly without freezing the computer. For the computer model construction, the following model input were used. They are-the processing times, number of machines, number of operators, number of tasks, number of helpers, quantity of input material per day, inter-arrival time of parts, productivity per day, working hours, quantity of input materials per day, task precedence relations, bundle sizes, job release policy, machine type, and production target. While the output variables from the Arena model included cycle time, idle time, resource utilization, throughput, defect, and work in progress (WIP). WIP was adopted to determine the global best line balancing condition.

2.1 Construction of Computer Model

In the construction of computer model or base model, several Arena simulation elements were used including entity, variables, resources, process, attribute, and transfer and control logic elements. The following model assumptions were used for simulation model development in this study:

a) The input materials arrived in production line at constant time, that is, every day and there was no shortage of materials from cutting department.
b) There was no breakdown of the machines in the production line.
c) There were no absenteeism of the operators and helpers, and so the workstations are never stopped due to absence of the operators or helpers.
d) Helpers were not allowed to operate any machine, only operators are assigned to machines. Therefore, the numbers of operators were equal to the number of machines and increasing machine number also increases operator number and vice versa.
e) The daily production shift was 8 hours, and there was no overtime considered.
f) Infinite buffer (workstation's bundles or workpieces storage) capacity was considered which implies that the buffer at each workstation could never be full.

2.2 Simulation Method

In order to build a model of a complex trouser assembly line, four separate simulation models were developed and then combined as shown in Figure-2.

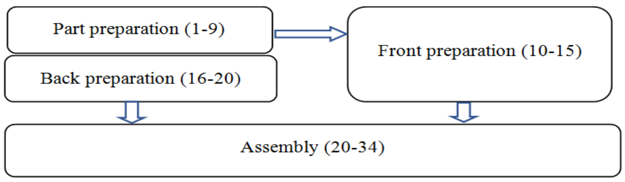

Figure-2. Computer simulation model construction approach for this study.

Part preparation (PP) module consists of nine sub-operations; the front part preparation (FP) module consists of six sub-operations; the back part preparation consists of four sub-operations; and the assembly operation (AO) consists of fifteen sub-operations. The precedence relationship between the operations is shown in the Figure-3.

VOL. 17, NO. 4, FEBRUARY 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

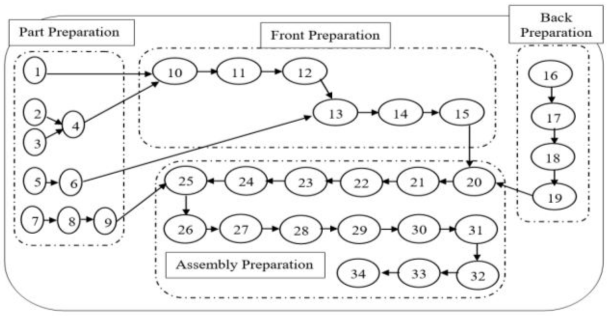

Figure-3. Precedence relationship of the operations.

The construction of simulation models with Arena, involved using modeling shapes called module- from the basic process, advanced process, and advanced transfer panels. These modules are used as the building blocks in developing a simulation model. There are two types of modules- data module and flowchart module. Data modules (resource, queue, variable, schedule, and set) are user to manipulate in the spreadsheet interface, which are not placed in the model window. While, the flowchart modules are used in model window to connect data modules to form a flowchart, which describes the logic of model. In the present study, the flowchart modules from three Arena project bars were utilized: basic process (create module, batch module, separate module, assign module, record module, process module, and decide module), advanced process (hold module and match module), and advance transfer (station module and route module).

The Arena flowchart modules used in this study were as follows:

Create module was used to mimic the trouser parts bundles' arrival from the cutting department to the assembly line. The number of Arena create modules used were (six) equal to the number of operations on the trousers that do not have precedence operations.

Batch module was used to combine individual cut pieces into bundles to be moved to the next operators. Specifically, batch operation is used to make the computer understand that the operation can only be performed when all precedence operations are performed.

Separate module was used to separate the bundles of workpieces to be seized and released as a single workpiece by the operators.

Assign module was used to add attributes names, pictures, and variables to the entities (trouser parts bundles or workpieces).

Record module was employed to count the throughput at end of part preparation, front preparation, back preparation modules and the full assembly line.

Process module was used to model the working of resources (machines, helpers, quality personnel) in completing the given tasks. In fact, each process module was used to represent the one resource at each workstation. This implies that total process modules used were equivalent to the total number of the available resources in the trouser assembly line. Operator and machine were modeled as single resource, but denoted as machine of different types.

Decide module was used to make decision on bundles or workpieces distribution to the resources in the same workstation. It was also used to model the task assignment pattern to operators whether equal workload or unequal workload on the operators performing similar tasks, moreover, it was used to decide on quality whether rework required or not.

Hold module was used to model job release policy based on the work in process (WIP) threshold of the bottleneck workstation. It holds the bundles generated by the create module and only releases some bundles restricted by the set WIP threshold of the bottleneck workstation. The bottleneck workstation is the one whose capacity is less than the demand placed on it and less than the capacities of all other resources. WIP is the number of unfinished bundles or workpieces in the workstations.

Match module was employed to combine two or different parts bundles to a workstation. In addition, four Arena models developed were combined using match module to form a full trouser assembly line model. By using match module, all trouser parts bundles and workpieces were captured, and in case of missing parts, there could be no trouser output at end of the assembly line.

Station and Route modules are complementary modules of advance transfer. They were used to replace the modules connecting links which eliminated the congestion of the simulation model.

Dispose module was used as the exit for finished trousers at end of the assembly line.

All these Arena modules played great roles in building simulation model of the complex trouser assembly line. The line diagram of complex trouser is presented in Figure-4. Basically, developing a simulation model involved identifying one or more flow objects known as entities that flow through the system and then building a flowchart of the model using Arena's flowchart modules. In the simulation of trouser assembly line, the bundles arrive in the line with the inter-arrival time of 8 hours, the bundles were held at the bundle arrive table using hold modules, which were then transferred to the specific workstations using the route and station modules.

VOL. 17, NO. 4, FEBRUARY 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

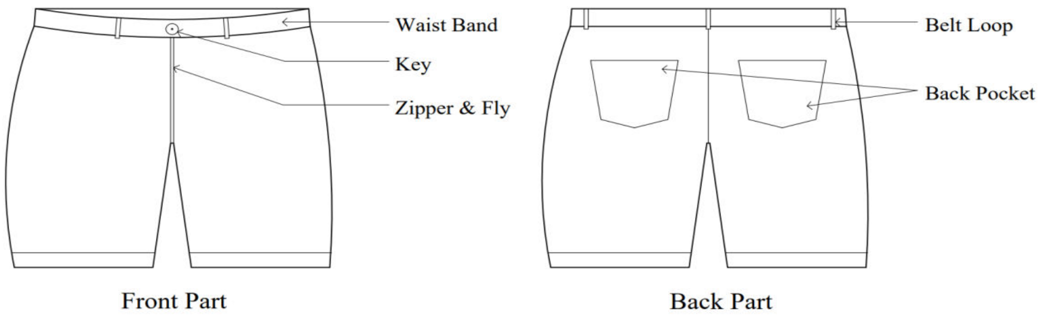

Figure-4. Line diagram of the trouser.

The actual model constructed and used for simulation in Arena software is show in the Figure-5. The initial measured readings of all the 34 operations are given as input for the simulation. The input analyzer is used to generate the distributions of the standard times and the distribution type which best fit the data along with the squared error is presented in the Table-1. The expression from the input analyzer are given as the input for the simulation model and the model is run 30 times for consistency and repeatability of the results. The simulations model is constructed following the precedence relationship among the operations. The results of the simulation model- with utilization time in minutes, instantaneous utilization in initial scenario and proposed simulation model along with percentage improvement in instantaneous utilization of each work station is shown in the Table-2.

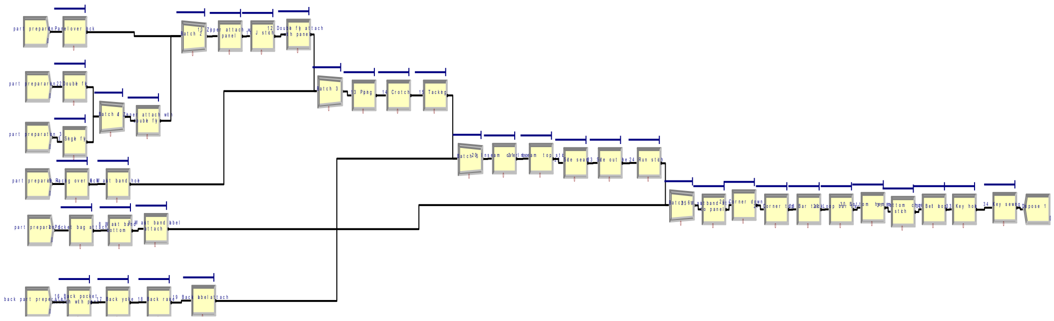

Figure-5. Actual simulation model constructed using Arena software.

VOL. 17, NO. 4, FEBRUARY 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Table-1. Input analyser details.

No.	Distribution Type	Square Error	No.	Distribution Type	Square Error
1	Lognormal	0.028663	18	Erlang	0.034774
2	Normal	0.018783	19	Gamma	0.039749
3	Weibull	0.044541	20	Normal	0.113473
4	Beta	0.060581	21	Normal	0.018896
5	Erlang	0.051806	22	Exponential	0.046841
6	Weibull	0.006341	23	Erlang	0.011245
7	Erlang	0.012415	24	Weibull	0.004709
8	Normal	0.035185	25	Gamma	0.021644
9	Normal	0.039306	26	Normal	0.038127
10	Normal	0.014565	27	Weibull	0.030429
11	Lognormal	0.009664	28	Normal	0.047586
12	Lognormal	0.030618	29	Beta	0.009170
13	Lognormal	0.005908	30	Gamma	0.023604
14	Lognormal	0.008353	31	Erlang	0.015350
15	Gamma	0.068916	32	Exponential	0.026832
16	Weibull	0.026514	33	Lognormal	0.002838
17	Lognormal	0.021094	34	Beta	0.022056

ARPN Journal of Engineering and Applied Sciences

Table-2. Results of simulation method.

Work Station	Total Utilization time (min)	Instantaneous Utilization	Instantaneous Utilization	Percentage Improvement
		Initial scenario	Simulation	
1	64	0.133	0.1461	9.85
2	104	0.217	0.226	4.15
3	48	0.100	0.12	20.00
4	88	0.183	0.2123	16.01
5	80	0.167	0.199	19.16
6	80	0.167	0.2886	72.81
7	96	0.200	0.2258	12.90
8	144	0.300	0.3461	15.37
9	144	0.300	0.334	11.33
10	216	0.450	0.5021	11.58
11	208	0.433	0.5057	16.79
12	208	0.433	0.4627	6.86
13	280	0.583	0.6643	13.95
14	248	0.517	0.5643	9.15
15	224	0.467	0.5226	11.91
16	344	0.717	0.793	10.60
17	128	0.267	0.3007	12.62
18	192	0.400	0.4413	10.33
19	224	0.467	0.5181	10.94
20	208	0.433	0.4661	7.64
21	280	0.583	0.6322	8.44
22	304	0.633	0.7011	10.76
23	264	0.550	0.5991	8.93
24	456	0.950	0.9987	5.13
25	256	0.533	0.4463	-16.27
26	256	0.533	0.5887	10.45
27	264	0.550	0.6178	12.33
28	288	0.600	0.6677	11.28
29	264	0.550	0.6083	10.60
30	304	0.633	0.6899	8.99
31	312	0.650	0.7041	8.32
32	256	0.533	0.5833	9.44
33	120	0.250	0.2829	13.16
34	56	0.117	0.1421	21.45

3. RESULTS AND DISCUSSIONS

The garment assembly line's productivity is checked in the initial scenario and results are tabulated in Table-2. The same data is feed to Arena software for simulation and the proposed model based decision support system is implemented. The results of the percentage utilization of all the work stations are tabulated in the Table-2. The initial result shows a prominent improvement in the utilization of the work stations as shown in the Figure-6. The percentage utilization increased for all the work stations except for the work station number 25, where simulation results are less than that of the initial scenario results. This is because of the fact that there is a large variation in the observed values during time study measurements. Due to the large variations the input analyzer for the Arena software could not actually fit a curve that can meaningfully comprehend the observed data. In the initial scenario, of the available 480 minutes, the total time utilization was only 206.11 minutes which accounts for 42.90 percent. The proposed methodology using simulation resulted in an increase of over-all utilization by 12.58 percent.

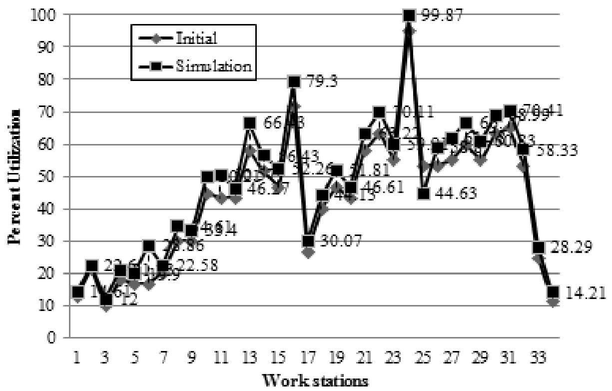

Figure-6. Work station’s instantaneous utilization.

4. CONCLUSIONS

In the present study the existing garment assembly line efficiency is compared with a novel computer simulation technique incorporating a model-driven decision support system. The proposed methodology incorporating model driven decision support system using Arena simulation of a garment assembly line has shown a net improvement of 12.58 percent in the utilization of the work stations in the assembly line over the existing situation. The results of this study will help the garment industry to optimize the utilization of resources through effective line balancing. This research can be further extended to considering bottle-necks in the assembly line and removing them by adding extra resources like operators and/or machines to improve the line efficiency and there by productivity.

REFERENCES

[1] M. Manaye. 2019. Line Balancing Techniques for Productivity Improvement. International Journal of Mechanical and Industrial Technology. 7(1): 89-104.

[2] R. Quarcooh, M. E. Gavor and D. Tetteh-Coffie. 2013. Challenges Facing Garment Producing Industry under AGOA in Ghana. International Journal of Clothing Science. 2(1): 9-14.

[3] A. Akdogan and A. S. Vanli. 2020. Introductory Chapter: Mass Production and Industry 4.0. Mass Production Processes. Vol. 3.

[4] S. A. Kumar and N. Suresh. 2006. Production and Operations Management. New Age International.

[5] N. Acar and S. Estas. 1991. Planning and Control Studies on Discrete Manufacturing Systems. National Productivity Center Publications. 309.

[6] C. Becker and A. Scholl. 2006. A survey on Problems and Methods in Generalized Assembly Line Balancing. European Journal of Operational Research. 168(3): 694-715.

[7] A. Scholl and C. Becker. 2006. State-of-the-Art Exact and Heuristic Solution Procedures for Simple Assembly Line Balancing. European Journal of Operational Research. 168(3): 666-693.

[8] G. Suresh, V. V. Vinod and S. Sahu. 1996. A Genetic Algorithm for Assembly Line Balancing. Production Planning & Control. 7(1): 38-46.

[9] J. Prokopenko. 1987. Productivity management: A Practical Handbook. International Labour Organization.

[10] D. Kitaw, A. Matebu and S. Tadesse. 2010. Assembly Line Balancing using Simulation Technique in a Garment Manufacturing Firm. Zede Journal. 27: 69-80.

[11] L. Mulugeta. 2021. Productivity Improvement through Lean Manufacturing Tools in Ethiopian Garment Manufacturing Company. Materials Today: Proceedings. 37: 1432-1436.

[12] J. C. Chen, M.H. Hsaio, C. C.Chen and C. J. Sun. 2009. A Grouping Genetic Algorithm for the Assembly Line Balancing Problem of Sewing Lines in Garment Industry. IEEE International Conference on Machine Learning and Cybernetics. 5: 2811-2816.

[13] M. Kayar and Ö. C. Bulur. 2020. Investigation of the Primary Reason Leading to Apparel Companies to Outsource. International Journal of Innovative Research and Reviews. 4(2): 1-4.

[14] J. Prokopenko. 1992. Productivity Management: A Practical Handbook. 2nd Edition, International Labour Office, Geneva, Switzerland.

[15] R. Subhashini and N. Varghese. 2021. Methods of Improving Productivity in Apparel Industry. International Journal of Research in Engineering, Science and Management. 4(4): 130-141.

[16] R. Kumar, P. Kalra and S. Kant. 2020. Productivity Enhancement of Assembly Line by using Maynard Operation Sequence Technique after Identification of Lean Wastages. International Journal of Productivity and Quality Management. 29(4): 463-482.

[17] D. A. Legesse and A. P. Singh. 2014. Productivity Improvement through Lean Manufacturing Tools: A Case Study on Ethiopian Garment Industry. International. Journal of. Engineering Research and. Technology. 3(9): 1037-1045.

[18] N. Malekjani and S. M. Jafari. 2018. Simulation of Food Drying Processes by Computational Fluid Dynamics (CFD); Recent Advances and Approaches. Trends in Food Science & Technology. 78: 206-223.

[19] M. Chraibi, A. Farah, S. Lebrazi, O. El Amine, M. I. Houssaini and K. Fikri-Benbrahim. 2016. Antimycobacterial Natural Products from Moroccan Medicinal Plants: Chemical Composition, Bacteriostatic and Bactericidal Profile of Thymus Satureioides and Mentha Pulegium Essential Oils. Asian Pacific Journal of Tropical Biomedicine. 6(10): 836-840.

[20] A. M. Atieh, H. Kaylani, Y. Al-Abdallat, A. Qaderi, L. Ghoul, L. Jaradat and I. Hdairis. 2016. Performance Improvement of Inventory Management System Processes by an Automated Warehouse Management System. Procedia Cirp. 41: 568-572.

[21] Z. Alwadood, I. Kassim and R. M. Rani. 2010. Maintenance Workforce Scheduling using Arena Simulation. IEEE Second International Conference on Computer Research and Development. pp. 517-521.

[22] S. Kavakeb, T. Thanh, N. Kay, M. Zaili, Y. Jenkinsona and R. Murray. 2015. Green Vehicle Technology to Enhance the Performance of a European Port: A Simulation Model with a Cost-Benefit Approach. Transportation Research Part C: Emerging Technologies. 60: 169-188.

[23] E. Orta, M. Ruiz, N. Hurtado and D. Gawn. 2014. Decision-making in IT service management: A Simulation based Approach. Decision Support Systems. 66: 36-51.

[24] N. M. Z. N. Mohamed, M. F. F. A. Rashid, A. N. M. Rose and W. Y. Tin. 2014. Production Layout Improvement for Steel Fabrication Works. Journal of Industrial and Intelligent Information. 3(2).

[25] S. R. Vijayakumar and S. Gajendran. 2014. Improvement of overall equipment Effectiveness (OEE) in Injection Moulding Process Industry. IOSR Journal of Mechanical and Civil Engineering. 2(10): 47-60.

[26] E. Westkämper. 2007. Digital Manufacturing in the global Era. Digital Enterprise Technology, Springer, Boston, MA. pp. 3-14.

[27] F. F. Chen. 2009. Decision support for lean practitioners: A Web-based Adaptive Assessment Approach. Computers in Industry. 60(4): 277-283.

[28] E. B. Mohamad, M. A. B. Ibrahim. L. Sukarma, M. A. A. Rahman, A. S. B. Shibghatullah and M. R. B. Salleh. 2017. Improved Decision Making in Lean Manufacturing Using Simulation-Based Approach. International Journal of Agile Systems and Management. 10(1): 34-48.