JJMIE

Volume 16, Number 5, December. 2022
ISSN 1995-6665
Pages 811– 819

Jordan Journal of Mechanical and Industrial Engineering

An Integrated Systematic Approach for Reconfiguration of Facilities Layout in a Stochastic Product Demand

A.A. Abdul Rahman[1,2*], R.N.H. Leong[1], O.J. Adeboye[1], E. Mohamad[2], T.J. Yee[1], M.H. Md Saad[2]

[1]*Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Melaka, Malaysia.*

[2]*Institute of IR4.0, Universiti Kebangsaan Malaysia, Bangi, Selangor, Malaysia.*

Received 1 Aug 2022 *Accepted 31 Oct 2022*

Abstract

A factory layout is designed to obtain a physical arrangement of different entities of a facility that most economically meets the required output, in terms of both quantity and quality. An optimum and good arrangement can make the flow of the material free from any interruption and will increase the productivity. New challenges to the manufacturing layout will occur when there is an increase in demand for customer-specific products, and an increasingly shorter product life cycle. Manufacturing companies that undergo production expansion to their current facilities without careful facilities planning, would in most situations, encounter many issues which could retard their overall operations. Due to ever reducing space in the plant, when a transfer is done, this causes tremendous pressure on its current facilities, causing several production bottlenecks and affecting productivity. The aim of this study is to develop a systematic integrated approach to re-configure its current layout to an optimum layout under this stochastic product demand. The approach is to select three key production optimization methodologies based on their individual strengths for the specific task required in developing this integrated approach. The development of this integrated approach takes into consideration the combination of these three key methodologies of the production optimization into a process flowchart, which are the Systematic Layout Planning (SLP), the Theory of Constraint (TOC), and the Discrete Event Simulation (DES). The step of developing the alternative layout is an integration of SLP with the TOC. The translated layouts were then validated by comparing the layout as it is (AS-IS) or the existing layout with the alternative layouts and analysed with the DES for the optimum layout in terms of productivity. The results from the case study revealed that Option 2 which was developed through this integrated approach is the optimum layout. Via this integrated approach, the throughput per hour of Option 2 improved by 15% over the existing layout and by 23% over the Option 1 layout. Total distance covered for the forklift movement with Option 2 shows a much lower distance travelled than the other two layouts. This study reveals the effectiveness of the developed integrated approach in developing the optimized layout with a better material flow strategy.

Keywords: Material Flow Analysis; Manufacturing System; Plant Simulation; Factory Layout; Production Optimization.

1. Introduction

Factory can be referred to as an industrial site, usually containing buildings and machineries where workers operate machines to manufacture and process goods from one product into another. The re-layout of a factory or facility design is aimed at improving the productivity of machines, designing an effective workflow, workers, and material flow [1].

Re-layout for a factory is important to improving and expanding the efficient production process and addressing the requirements of workers [2]. It is also important because it affects the flow of material and processes, labour efficiency, supervision and control, use of space and expansion possibilities, etc. [3]. A well-designed and structured manufacturing layout plan can reduce up to 50% of the operating cost and improve productivity [4]. A poor layout results in wasted time and energy and creates confusion [5].

The most used techniques or methods that can be utilized to design and redesign a facility layout is the Systematic Layout Planning (SLP) by Muther, 1961 [6]. This is a phase in preparation to manage and control the layout of the factory Systematic Planning System (SLP) aims at achieving the quickest material flow at the lowest cost and least amount of material handling during the manufacturing process [7][8][9]. This study is conducted in collaboration with ABC Company. The factory is located in Melaka, Malaysia. A company established in Malaysia for over 44years specialized in manufacturing and supply of diverse, quality and innovative soft and hard haberdashery products and knitting accessories.

* Corresponding author e-mail: azrulazwan@utem.edu.my.

ABC company over the years has gone through several expansion of relocation from other group overseas production sites, production machineries to its current site here in Malaysia plant. Most of these production expansions did not take into consideration proper facilities planning as it was done in a haste, just to allow the production of these new products to commence production in a short time.

The SLP approach is initiated by Muther (1961). This is an undertaking in the preparation and in the control of the layout of the factory SLP aimed at achieving the fastest material flow at the lowest cost and the least movement of material handling during the manufacturing process [10]. There was also a study showcasing the use of SLP in the food industry and in hospitals [11][12][13].

Table 1: Charts in SLP

Chart	Purpose
From-To chart	Quantitative measuring of movements between departments in terms of the amount transported.
Activity relationship chart	Find the most dependent department based on sequential activity.
Relationship diagram	Positioning activities or operations in which they are situated in a two-dimensional space.
Space relationship diagram	Present the space of each related departments.

According to Tompkins [14], the mechanism involved in the execution of the SLP is uncomplicated. However, this does not rule out that there will be no complications in the application of the SLP. This process requires several different charts and diagrams to be developed by the facility planner. The advantage of this process is that it leaves room for imagination which allows for easy grasping of concept adaption. The charts and diagrams created in this process are illustrated in Table 1.

Theory of Constraint (TOC) is a production management system to pinpoint and to eliminate the impact of bottlenecks in a company [15]. The TOC is a technique in identifying the most important limiting factor (i.e., constraint) that obstructs goal reaching and thereafter, systematically addressing the constraint issue till it ceases to be a limiting factor. In manufacturing, the constraint is often referred to as a bottleneck.

Material flow analysis is a systematic assessment of the flows and stocks of materials within a system defined in space and time. It connects the sources, the pathways, and the intermediate and final sinks of a material [11]. Material flow analysis and improvement of a manufacturing system due to factory re-layout can be carried out using several modelling software that provides analysis of its operations in dynamic environment. The process of imitation of the various operation involved in a real-world process or system [4] over time is called simulation.

In simulating a process or a system, it first requires an already established model. The model represents the system itself, whereas the simulation represents the operation of the system over time [16]. Based on the facts above, material flow analysis and layout optimization of a manufacturing system under stochastic demand [5] play a vital role in any facility planning and layout study [17]. Discrete Event Simulation (DES) is a common tool for production throughput analysis and manufacturing system performance optimization [18].

This study aim is to develop a methodological approach in assisting manufacturing companies which has undergone expansion in manufacturing facilities, to reconfigure or re-layout its current layout to an optimum layout.

The first objective is to study the state-of-the-art approach to re-configure facilities layout under stochastic demands [19]. The second objective is formulating a systematic approach based on the SLP, the TOC [20] and to develop a simulation-based approach for re-configuration of facilities layout. Another objective (3) is to validate this formulated algorithm and integrated approaches on ABC company. The final objective (4) is to evaluate the effectiveness of this approach with the state-of-the-art approaches. Two alternative layouts are developed using this approach and to determine its effectiveness, they are analysed using the DES of Tecnomatix Plant Simulation Software v14 to obtain key productivity data and to compare with the AS-IS layout data. Upon obtaining the results, the best of the two alternative layouts based on the optimum productivity data for the manufacturing production of ABC Company is selected.

2. Methodology

With the aim to develop a novel approach for layout reconfiguration, several steps were used in planning, development, validation, and analysis phases. Each step is designed to demonstrate the relationships and the interaction of the development. Figure 1 presents the methodology utilized in performing this study.

The study starts with analysing available state of the art approaches and methods, under development in research and implementation at the industries. After evaluation of all these methods, a selection will be made on which of these methodologies would be best suited for this study. The selected methodologies are then integrated together to formulate a novel approach that supports layout design and re-layout design process. The capability and effectiveness of this formulated systematic approach will then be validated by a real industrial case study from the ABC company.

In the context of this study, the combination of SLP, TOC and DES were selected and integrated. During the validation process, SLP procedures i.e., Form–To chart, Activity relationship chart, Relationship diagram and Space relationship diagram are created and analysed. Necessary data that relevant for the SLP is collected. This requires numerous visits to the site (ABC company).

Information gained from the SLP procedure is used to develop an AS-IS model. Modelling process follows the simulation project procedure proposed by the Association of German Engineers (Verein Duestcher Ingenieure -VDI). Based on the analysis of the AS-IS planned layout model the two alternatives layout models will be analysed and compared to the AS-IS layout model. Incorporating TOC to the development of the alternative layout is another key factor. Simulation evaluation will be done, and the best alternatives in terms of optimum material flow and higher throughput will be proposed for implementation.

2.1. Data Collection

This sub-session describes about the investigation method that is used to achieve the necessary information. The data collection method is the typically determining for the data analysis [21]. Through observations and interviews with engineering personnel was the data for the factory layout collected starting from raw material to packaging even to dispatch. The principal data collected spans from the type and nature of the product, their respective production process flow, factory layout and setup relative to the product discussed and need to recognize for all the process which incorporate into the production line.

The data demonstrate the present creation line and their material flow system for each product per production. Other than that, is the time for each number of workstations, working shift, processing time, frequency of forklift movement and the number of batched per demand. Besides, data is gathered, so that, the cycle time for each workstation in the production lines, and also the number of batches is transporting from a process to another process can be accounted for. With the data collected, the layout alternatives can be developed both on paper and then simulated.

2.2. Material Flow and Production Process

To further create the experimental model relative to the real-time model, all five products were studied thoroughly from the raw material stage to the level as it comes as a finished product. These products included (i) Safety Pins; (ii) Straight Pin; (iii) Snap fastener; (iv) Aluminium Imra hook; (v) Aluminium Susan bates. Table 2 shows the production process and data collection of the safety pins product as an example. Similar data has been collected for other four products.

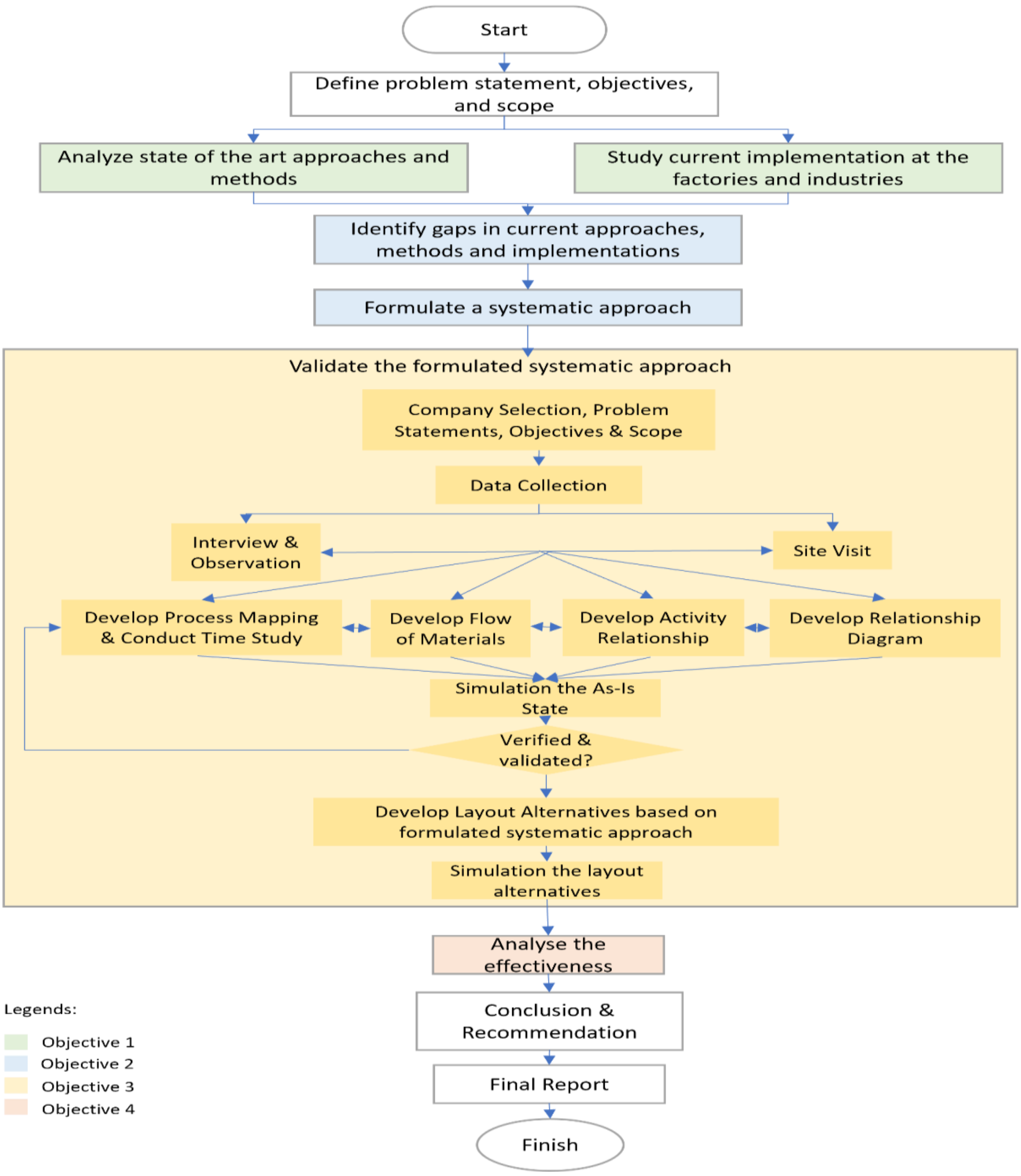


Figure 1. Methodology of the study

Table 2: Example of data collection for safety pins product

Process	Processing time	No. of machine	Batch size
Demand = 120kg			
Raw material	-	-	Pin – 24kg per batch x 5
Pointing	5hrs	5	120kg
Assembly	3hrs/batch	1	24kg per batch
Nikel plating	8hrs	1 shift	120kg
Buffer Storage Area	-		
Quality Control	5hrs		120kg
WIP and kitting area	2hrs	5	24kg per batch
Packaging	2hrs	5	24kg per batch

The manufacturing of all these products is subdivided into three factories, located within the same premises of the company. These three factories will be simulated using the Tecnomatix Plant Simulation software. The production process of each product differs, so every product has to be simulated based on their own production line respectively. This will allow the simulated or experimental model of the real-time model to be created of which later alternatives layout created utilizing the new integrated approach will be generated for final simulation analysis.

2.3. Develop Layout Alternatives

With the integration SLP and TOC into a single approach of layout re-configuration, several layout alternatives will be developed. The alternatives highlighting all the desired options that will go with the desired objectives; improve the overall throughput and material flow [22]. These alternative layout options are later compared with the existing or AS-IS layout by the simulation process with its differing factory arrangement, however, the process flow for production remains unchanged.

2.4. Simulation and Data Analysis

Upon the completion of data collection, the simulation model for all alternatives is then created. The simulation can be configured and reconfigured to match the desired objectives with the availability of a completed data. Simulation software uses a dedicated library or custom-designed computer support CAD data and allows flexibility of the appropriate visualization approach to demonstrate the project in a 2D virtual environment.

Experimentation with the model and applying the design of experiments techniques are happening at this step [23]. Further in this step, investigating decisions about other alternative models and the return to the initial steps of the process for each major model may change. Having the operation of the model studied and the properties associated with the workings of the actual system or sub-system, it can then be deduced accurately through the simulation.

Wide statistics and chart boards are used and shown to support a dynamic analysis of the performance parameters, including line workloads, crashes, idle time and fixes and the proprietary key performance factors. As an example, with the advantage of having a data analysis, bottlenecks can be pinpointed fast and various secondary channels can then be explored by comparing the working time, the waiting time, the processing time and the cycle time of the workstation.

3. Results and Discussion

3.1. Integrated Approach

The methodology for reconfiguring a plant or manufacturing layout, is crucial by first developing an integrated approach which is suitable and best suited for the application under this Stochastic Product Demand. As shown in Figure. 2, the integrated approach for layout re-configuration.

The development of this integrated approach takes into consideration of combining 3 key methodology of production optimization process. The first is to select the best layout procedure and, in this case, SLP was selected of the 5 layout procedures due to it's easy to understand and methodological steps. Although, the procedure to developed a good layout had been developed, the ever-changing stochastic product demand in the company will create potential bottlenecks in the production flow and this will create constraint which eventually retard productivity and throughput. In order to encounter these challenges, TOC was incorporated in this process flow as to ensure any bottleneck in the production flow is taken into consideration at this early stage of planning. The final key process to complete this integrated approach is to verify among the alternative layout, developed in the earlier steps was to select the best among them. And by including computer simulation in the last stage of the flow chart, would eventually lead to the most optimised selection of the layout, by means of generating key specific productivity data in this simulation process.

3.2. From-To Chart

A review is required in minimizing the material handling cost of flow among departments. In our layout design, the priority is to focus on the need to minimize the movements of materials; raw materials, semi-finished and\or finished goods from one process department to another and to reduce the bottleneck material flows.

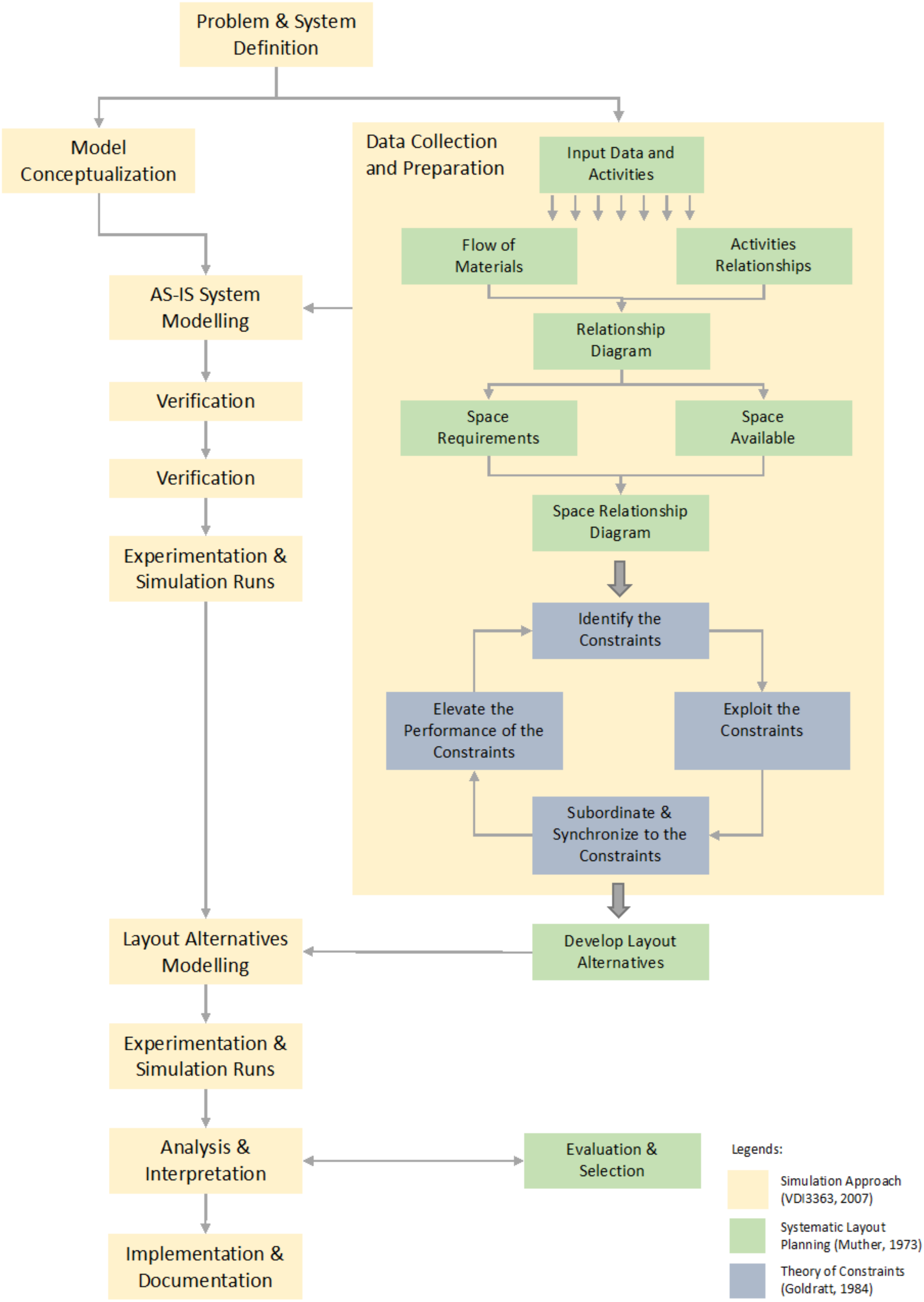


Figure. 2. Integrated Approach for Layout Re-Configuration

From \ To	Store	Pointing	Wire Forming	Assembly	Nickel plating	QC	BSA	Kitting	Packing	Warehouse / dispatch
	Frequency									
Stores		5	5							
Pointing				5						
Wire Forming				5						
Assembly					1					
Nickel Plating						5				
QC							1			
BSA								1		
Kitting									1	
Packing										1

Figure 3. Example of From-To chart for safety pins product

From figure 3 shows the sample from-to chart data for safety pin, using this data as a sample data to represent same procedure and data taken for other products. By the figure, it is clearly noted that the higher the numbers between the departments and to the departments intended, there is also a corresponding high frequency of the material travels. As such, considerable effort and care must be taken to locate them either closer together or to minimize the travel distances between these two departments in other to achieve the best possible optimized.

3.3. Activity Relationship Chart

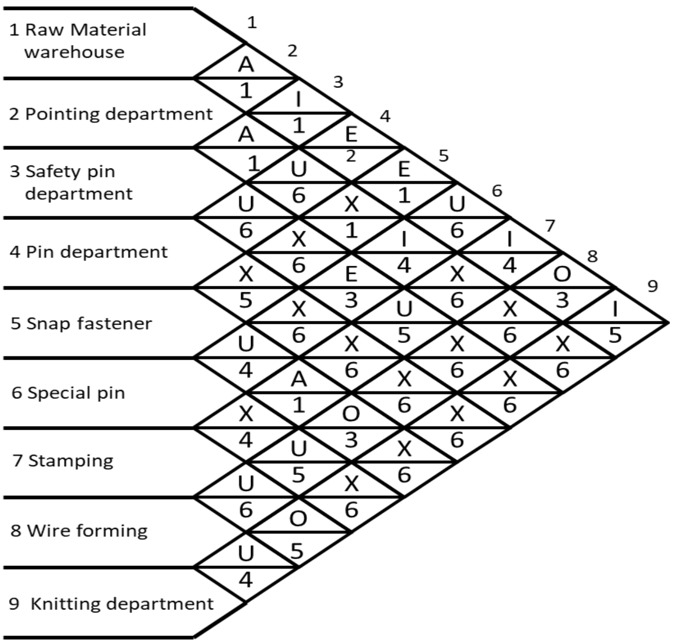
In Figure 4 for factory 1 represents the sample figure for the activity relation diagram for ABC company and this procedure is replicated for factory 2 and 3 respectively. The values may be recorded, with the reasons for the closeness value using the relationship chart because the Activity relationship chart, measures in quality definition, using the closeness relationship values. The aim is to maximize the closeness rating scores between departments based on a closeness function.

In figure 4, the location and position of every department depend highly on the rating of importance of the specific department and the high frequency of usages between them. This information must be taken into consideration when developing the alternative layouts as it will affect the material flows of the individual products.

3.4. Theory of Constraints

Upon completing the above From-To Chart, ARC, and Space Requirements, the next step is to determine if there will be any constraints of material flows if the TOC is applied. By applying the five focusing steps mentioned by [24] (identify the constraint, exploit the constraint, subordinate the constraint, elevate the constraint, and repeat the process) to each of the production process and by eliminating any possible constraints along the material process flow, this ensures the reduction of any potential bottlenecks. From the current layout, it is discovered that the bottleneck or constraint is evident at the WIP build-up due to inefficient handling of materials at the pointing and safety pins sections. By relocating the pointing and safety pins closer in the alternative layout, next to the raw materials store, this can potentially reduce this constraint.

This exercise is repeated for the other processes and departments throughout the factory for the elimination of all the constraints.



Value	Closeness
A	Absolutely necessary
E	Especially Important
I	Important
O	Ordinary closeness okay
U	Unimportant
X	Not desireable

Figure 4. Sample ARC Chart of Factory 1

3.5. Simulation Result and Analysis

Table 3 shows the total summary of all the results generated for all layout simulated using Tecnomatix Plant Simulation Software according to the fourfold analysis discussed.

Table 3. Summary of all the Simulation Results Obtained

Results	Existing Layout	Option 1	Option 2
Total Simulation Time (HH:MM: SS)	14:07:02	15:02:01	11:51.17
Working Percentage (%)	62.60%	62.22%	56.78%
Waiting Percentage (%)	37.40%	37.75%	43.32%
Total throughput (unit)	16	16	16
Throughput per minute	0.02	0.02	0.02
Throughput per hour	1.14	1.03	1.34
Throughput per day	26.47	24.68	32.19
No. of forklift used for production	3	3	2
Factory 1 forklift (Total distance traveled)	3920m	2396m	2396m
Factory 2 forklift (Total distance traveled)	1827m	2605m	2920m
Factory 3 forklift (Total distance traveled)	481m	832m	-
Total distribution time for Factory 1 (minutes)	48.39	28.58	28.58

After simulation on the existing layout and option 1 layout, certain results were acquired apart from the observed result that can be used to buttress our analysis to the subject matter in meeting the desired objectives. The analysis of the result is carried out in threefold namely;

1. Working, waiting and total simulation time.
2. Total throughput per minute, per hour, per day.
3. The number of forklifts used, and its distance travelled.

3.5.1. Working, Waiting, and Total Simulation Time

The total simulation time signifies the Summation of time required for the simulation all process for each layout to be completed. As the materials of each five product go in through the source and out through the drain then the total time is obtained. In analysing the result in table 3, it is seen that option 1 has higher total simulation time compared to the other layout, followed by the existing layout then option 2. The option 2 layout is seen to have possessed a lower total simulation time which therefore means that production will finish faster than the existing layout and the option 1 layout due to certain advantages the layout has over the option 1 and existing layout. The lower total simulation time option 2 possesses tends to take a step closer to validating the intended objective of this project. The improvement of the total simulation time of option 2 over the existing layout and option 1 is approximately 23% as illustrated in Figure 5.

Figure 5. Total simulation time of the three layouts

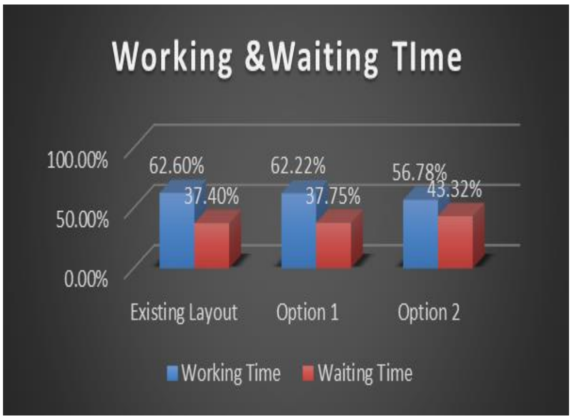


Figure 6. Working and waiting time of the three layouts

This is also validated through the working and waiting time of each option and the existing layout through the simulated results as shown in figure 6. Option 2 has a lower working time of about 10% reduction compared to the existing layout and the Option 1. Whether this will be a qualification for selection as the best-improved layout will be determined by the result of the other analysis.

3.5.2. Throughput of the Layout

The difference should be in the time it takes for it to exit which will help us define which layout will favour a system of stochastic demands. High throughput rate will be more productive thereby meeting the objective of this project. Option 2 has the highest number of throughput rate per hour and per day compared to the existing layout and option 1 layout as illustrated in Figure 7.

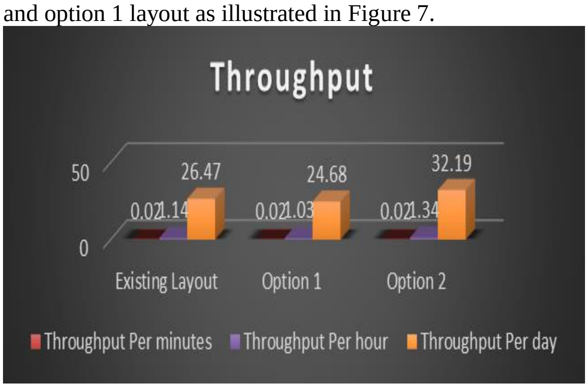


Figure 7. Throughput of the three layouts

The throughput per hour of option 2 is improved 15% over the existing layout and 23% over the option 1 layout while the throughput per day of option 2 seems to be improved 18% over the existing layout and 23% over option 1 layout. The throughput of each option reveals that option 2 possesses the highest throughput per hour and day which will show that option 2 will produce more output of products followed by the existing layout than the option 1. This validates the fact that it will be more preferable over the other layout as it produces the best result that meets the objectives of the study.

3.5.3. Total Distance Travelled & Number of Forklifts

Total distance covered for the forklift movement, option 2 shows a minimum total distance travelled even with 2 forklifts than existing and option 1 layout that utilized 3 forklifts for the full operation and option 2 was still able to meet the desired objective. From factory 2 and 3 of the option 1 shows the inefficiency of the developed option, intending to improve the production time and movement thereby increasing profitability. Factory 2 and 3 of option 2 shows a great measure of improvement compared to the existing layout alternative layout of option 1. With this improvement, there was improved forklift movement and total processing time as illustrated in Figure 8.

Figure 8. The distance travelled by the forklifts in the three layouts

4. CONCLUSION

From the above analysis and results obtained from the simulation, clearly revels the best layout option of the 2 developed using SLP and TOC methodology, was layout Option 2. The case study conducted in this thesis on ABC Company was to develop the best optimum layout using the proposed integrated systematic approach, resulting in terms of highest productivity by means of throughput, shortest travelling distance, and shortest working and waiting time in a stochastic demand environment.

The first objective was achieved with the selection of SLP after the study the state- of- the- art approaches of layout re-configuration in a stochastic demand.

The next objective was achieved with the development of the integrated systematic approach by combination of SLP with TOC methodology to generate alternative layouts. By simulating the alternative layouts, we are able to determine which of the alternative layouts would be the best choice for the re-layout process in terms of overall plant productivity. This formulated approach was validated in the case study conducted in a manufacturing company which was undergoing an expansion program.

Finally, the effectiveness of this formulated approach was confirmed through the result given by the case study. The best of the alternative layouts, with the highest throughput, least forklift utilization, least working and waiting time and shortest travelled distances was proposed for implementation. Option 2 layout was able to record an average of 50% improvement for factory 1 total distribution, 23% improvement to the overall total simulation time, 19% improvement to the average throughput per hour and 21% improvement to the throughput per day and 14% improvement of the total forklift distance travelled over the existing layout and option 1.

Acknowledgement

The authors would like to thank Universiti Teknikal Malaysia Melaka, ABC company and UTeM Zamalah Scholarship Scheme 2.0, for supporting this study.

References

[1] G. Kovács, S. Kot, "Facility layout redesign for efficiency improvement and cost reduction", Journal of Applied Mathematics and Computational Mechanics, Vol. 16, No. 1, 2017, 63-74.

[2] M. Iqbal, M. Hashmi, "Design and analysis of a virtual factory layout", Journal of Materials Processing Technology, Vol. 118, No. 1-3, 2001, 403-410.

[3] S. Ali Naqvi, M. Fahad, M. Atir, M. Zubair, M. Shehzad, "Productivity improvement of a manufacturing facility using systematic layout planning", Cogent Engineering, Vol. 3, No. 1, 2016.

[4] Y.H. Lee, M.K. Cho, S.J. Kim, B.Y Kim, “Supply chain simulation with discrete-continuous combined modeling”, Computers and Industrial Engineering, Vol. 43, 2002, 375-392.

[5] Smith J., Tan B., Handbook of Stochastic Models and Analysis of Manufacturing System Operations. New York, NY: Springer, 2013.

[6] Muther R., Systematic Layout Planning. 2nd ed. CBI Pub., 1973.

[7] Sule D.R. Manufacturing Facilities: Location, Planning, and Design, 3rd ed. CRC Press, 2008.

[8] Okpala, C., Chikwendu, Chukwumuanya, E. ‘Plant Layouts’ Analysis And Design’, International Journal of Advanced Engineering Technology, Vol. 7, Issue III, 2016, 0976-3945.

[9] J. Kolińska, R. Domański, “The Analysis of Production Lines Bottlenecks–Identification and Ways of Management”, 17th International Scientific Conference Business Logistics in Modern Management, Osijek, Croatia, 2017.

[10] Buchari, U. Tarigan, M. Ambarita, “Production layout improvement by using line balancing and Systematic Layout Planning (SLP) at PT. XYZ”, IOP Conference Series: Materials Science and Engineering, Sumatera Utara, Indonesia, 2018.

[11] Lin, Qing-Lian, “Integrating systematic layout planning with fuzzy constraint theory to design and optimize the facility layout for operating theatre in hospitals”, Journal of Intelligent Manufacturing Vol. 26, 2015, 87–95.

[12] Y. Ojaghi, “Production layout optimization for small and medium scale food industry”, Procedia CIRP. Elsevier B.V., Vol. 26, 2015, 247–251.

[13] S. Helber, “A hierarchical facility layout planning approach for large and complex hospitals”, Flexible Services and Manufacturing Journal, Vol. 28, No. 1, 2016, 5–29.

[14] Tompskin J.A., White J.A., Bozer Y.A., Tanchoco J.M.A., Facilities Planning. 4th ed. John Wiley & Sons, 2010

[15] Goldratt E., Cox J. The Goal. New York: North River Press; 1984.

[16] Talumis. What is simulation | Simulation Software Explained. [online] Available at: https://www.talumis.com/what-is-simulation/ [Accessed 26 Nov. 2019].

[17] E. Grajo, "Strategic layout planning and simulation for lean manufacturing a LayOPT tutorial", Proceedings of the 27th conference on Winter simulation, Arlington, Virginia, USA, 1995.

[18] O. Bataineh, R.A. Aomar, A.A. Shakra, “Simulation-based optimization for performance enhancement of public departments”. Jordan Journal of Mechanical and Industrial Engineering, Vol. 4, No. 3, 2010, 1995-6665.

[19] A. Azab, A. Ziout, W. ElMaraghy, “Modeling and optimization for disassembly planning”. Jordan Journal of Mechanical and Industrial Engineering, Vol. 5, No. 1, 2011, 1995-6665.

[20] S.A. Altarazi, N. Mandahawai, K. Gharaibah, “In-Production Product Value: A New Method for Part Type Prioritization”. Jordan Journal of Mechanical and Industrial Engineering, Vol. 4, No. 2, 2010, 1995-6665.

[21] Jupp V., Sapsford R., Data collection and analysis. London: SAGE, 1996.

[22] W. Wan Mahmood, M. Rahman, M. Baba, J. Ghani, "Improving Production Line Performance: A Case Study", Applied Mechanics and Materials, Vol. 44-47, 2010, 4136-4140.

[23] T. Abebe, 2020. Introduction Of Simulation Process. [online] Academia.edu. Available at:<https://www.academia.edu/4991660/Introduction_of_Simulation_Process> [Accessed 22 June 2020].

[24] Z. T. Şimşit, N. S. Günay, and Ö. Vayvay, “Theory of constraints: A literature review,” Procedia - Social and Behavioral Sciences, Vol. 150, 2014, 930–936.