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Research Article

PRODUCTION LAYOUT EFFICIENCY IMPROVEMENT FOR ARMOURED VEHICLE ASSEMBLY LINE

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ABSTRACT

The facility layout is the main problem that will be focused in this paper. This problemaffects the efficiency of the assembly line, which also will give a direct impact to the production performance. The main objective is to design a new alternative plant layout based on existing plant layout studyand evaluation of the proposed alternative layouts using Systematic Layout Planning procedure (SLP). The performance of alternative layout wasdeterminedby using Line Balancing method. This project was conducted in one of military vehicle manufacturing company in Pahang, Malaysia. Nevertheless, this research managed to provide better understanding and valuable information on the effectiveness of plant layout, which can give impact on performance of the production. Recommendations were made to improve the plant layout in order to provide a better performance in production activity and product quality.

INTRODUCTION

Nowadays, manufacturing industry facingmany challenges in today's market environment. The most significant challenges are dealing with intense global competition, finding and keeping skilled labor, handling cost pressures, and adapting to different consumer needs. High efficiency of production system is vital in most manufacturing company to accomplish their operation. People, equipment, and procedure designed are the main combination that drives the company's operations (Mohamed, 2012). As discussed in (Anucha Watanapa, 2011), elimination of obstructions in material flow can achieve maximum productivity. Manufacturers company whose fail to deliver on time will fail to keep their customers (Roslin, 2008). This reality is all the main reason why small and mid-sized manufacturers mustdeliver their products into customers' hands as soon as possible (Roslin, 2008). The bottlenecks issue in the production process make this vision seems impossible. Plant layout design has become a fundamental basis of today's industrial plants which can influence parts of work efficiency. It is needed to appropriately plan and position employees, materials, machines, equipment, and other manufacturing supports and facilities to create the most effective plant layout.In the present, there are several methods for plant layout design such as systematic layout planning (SLP), algorithms, and arena simulation can apply to design plant layout as stated in (Zhu, 2009). SLP method has been studied to design the overall layout of log yards, the result showed the good workflow and was possible rearrangement pant layout under significance (Thomas Lacknsonen, 2010). Plant layout analysis and design for multiproduct line production has been studied. This work was carried out to investigate the suitable plant layout design for denture manufacturing. The suitable plant layout models were designed and compared the efficiency between current and new plant layout. Moreover, line balancing was done to allocate human resource by using line balancing calculation to find the increasing productivity of the new improvement layout. These reflect the importance of the plant layout design to bring about an increase in productivities. According to (Bukchin, 2000), the important parameters in Line Balancing are define as follow:

Line Efficiency = (Total Station Line Time ÷ Cycle time x number of workstations) x 100%

Balance Delay = (Total Idle Time ÷ Total available working time) x 100%

According to (Mat Saman *et al*., 2010), the three manual line balancing methods (LCR, KWM and Ranked Positional Weight) and four generated alternatives plant layout had been used in the research to balance the assembly line of automotive manufacturing company.As a result,productionefficiency increased about three times greater than existingassembly line. This improved assembly line is further verified by time study

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techniques. The goal is to obtain an optimum layout in terms of line efficiency and productivity rate. According to (Mahto, 2012), Kilbridge-Wester Heuristic approach and the Helgeson-Birnie Approach were design an assembly line starting from the work breakdown structure to the final grouping of tasks at works station. Optimizationof crew size, system utilization, probability of jobs being completed within a certain time frame and system design costs are the main target of this paper (Mahto, 2012). Material flow and tool usage were the two major problems to be solved in order to optimize the efficiency and production effectiveness throughout the implementation of the new alternative layout (Mahto, 2012). Therefore, this paper implements the combination of SLP procedures method and the Line Balancing method. Through this study, a balanced new alternative layout was developed with higher efficiency. Potential cost reduction and efficiency improvements were achieved.

Existing layout study

The purpose of studying the existing layout is to know how well the layout performance in productivity and quality terms. Data gained will be used as the main reference or base line for this study in order to design a new layout improved with high productivity and good quality. Time studytechnique wasused to gain a standard time to perform the specific assembly installation. The distance between storage and assembly station, working load of every task and space requirement was studied and all data collected were being tabulated.

Systematic layout planning

By using the SLP procedures, the advantages and disadvantages of the existing layout can be determining. Several criteria were choosing to identify the root cause of the efficiency problem. The relationship chart was developed to know how close the installation relationship to each related station. The following definitions are based upon the Systematic Layout Planning method or SLP by Muther (Richard Muther, 1994) as shown in Figure 1.0.

Line Balancing

Base on (Kamlekar1 *et al*., 1730), line balancing can be defined as the process to minimize the imbalance between machine and personnel while meeting a required output from line assembly.This method was done right after selection of alternative layout by implementing systematic layout planning procedures. Then the time requirement of each assembly line must be determined. In this research, Kilbridge and Wester's Method (KWM) and Largest Candidate Rule (LCR) were used. This are the heuristic procedure, which selects work elements for assignment to stations according to their position in the precedence diagram. There are several steps involving which can be simplified are as follow:

- The precedence diagram will be constructed so that the nodes with identical precedence are arranged vertically in columns.
- Organize element according to column with the element in first column listed first
- The elements then being assigned to workstations start with the first column element. The assignment procedures continuein order of column number until the cycle time is reached.

Layout efficiency calculation

Smoothness index, *SI* is an index that indicates the relative smoothness of a given assembly line balance. A smoothness index of zero indicates a perfect balance.It is being calculated by formula:

$$SI = \sqrt{\sum_{i=1}^{n}(T_s - T_{si})^2}$$

SI = Smoothness Index; n = number of station; T_s= Max available service on the line;T_{si}= service time at station *i.*

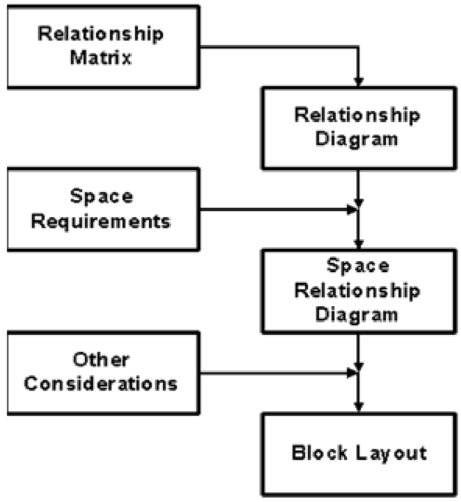

Figure 1. Systematic Layout Planning method (Richard Muther, 1994)

Line balance efficiency, E_b is the ratio of total station time to the cycle time multiplied by the number of work station

It is being calculated by formula:

$$E_b = \frac{T_{wc}}{wT_s} \times 100\%$$

E_b = Line Balance Efficiency; T_{wc} = work content time per product;

W = number of worker

Balance delay, *d* is measurement of the line inefficiency which results from idle time due to imperfect allocation of work between station. In other words, the balance delay is the percentage of wasted time or 100% - the efficiency.

$$d = 1 - E_b$$

RESULTS AND DISCUSSION

The existing plant layout was evaluated by using systematic layout planning procedures (SLP) for a better plant space utilization and increased productivity. The analysis of the existing plant layout was conducted first by studying aspects like flow of material and activity relationship resulting in the relationship diagram.

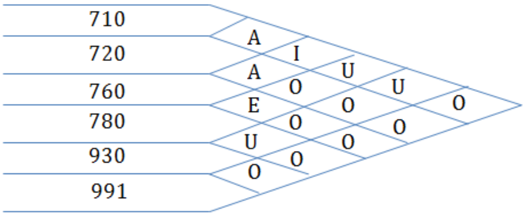

Figure 2. Relationship diagram

The diagram above shows that the closeness analysis between main station. The closeness analysis is rank by:

A (Absolutely necessary) – if the percentage relationship between stations is higher than 50%
E (Especially important) – if the percentage relationship between stations is higher than 40%
I (Important) – if the percentage relationship between stations is higher than 20%
O (Ordinary) – if the percentage relationship between stations is higher than 10%
U (Unimportant) – if the percentage relationship between stations is less than 10%
X (Undesirable) – no relation

Table 2. Details assembly activities by station from the existing layout and current operation sequences

Station	Sequence	Detail activities
710	00	Tapping Operation Before Mounting Process
	05	Nipel Installation Of Ctis, Brake, Hydra
	05	Lighting System Installation
	10	Electric System Installation
	10	Suspension System Installation
	10	Marking Installation
	15	Hydraulic System Installation
	15	Electric System Installation
	15	T.C.Inst, Drivetrain
	20	Tc Cover & Bilge Pump Installation
	20	Pneumatic System,General Interference
	25	Drive Train Installtion (Partly) & Park
	25	Ctis System Installation
	30	Steering System Installation
	30	Hydraulic Installation,Exterior
	35	Fuel System Installation
720	05	Water Propulsion System Installation
	05	Electric System Installation
	05	Hydraulic Inst, Winch Housing
	10	Brake System Installation.
	10	Electric System Installation
	10	Frontal, Spall Liner Installation
	10	Top, Spall Liner Installation
	10	Upper Lhs, Spall Liner Installation
	10	Sponson Lhs, Spall Liner Installation
	10	Upper Rhs, Spall Liner Installation
	10	Sponson Rhs, Spall Liner Installation
	15	Lighting System Installation
	15	Bulkhead Installation
	15	Pneumatic System, Supply Interface
	20	Intercom Installation
	20	Pneumatic Wiper,SystemInstallation
	20	Bilge Pump Installation
	25	Laser Warning Installation
	25	Pneumatic System Installation

The analysis then continued by producing space relationship diagram from gathering the data of space requirement and space available. The relationship diagram shows as in Figure 2.0.

Table 2. Continue

Station	Sequence	Detail activities
760	05	Control and Display Installation
	05	Ac System Installation
	10	Binnacle Installation
	10	Armor Installation
	15	Nc Detection Installation
	15	Wheel Installation
	20	Communication System Installation
	25	Fire Extinguisher System Installation
	26	Self Recovery Winch Installation
	30	Fire Suppression System Inst.
	35	Nbc System Instl
	40	Powerpack Installation
	45	Cooling System Instl
780	05	Bulkhead Installation
	10	Turret Support Installation
	11	Periscope Installation
	13	Wiper Instl
	15	Winch Covers Inst
	20	Trim Vane Installation
	25	Grill Installation
	30	External Volume Installation
	35	Bumper Installation
	40	Ramp Instl
	45	Drivers Hatch Assy. Personnel Hatch
	45	Drivers Hatch Assy. Personnel Hatch
	50	Personel Hatch Assy. Crew Hatch Inst.
	55	Mirror Installation
	60	Tow&Lifting System Installation
	65	Heater Installation
930	05	Floor Plate Installation
	10	Ammunition Stowage Installation
	15	Seat Installation
	20	Safety Screen Installation
	25	One Man Turret Installation
991	05	Stowage Installation
	10	Swim Curtain Inst
	15	Marking Installation
	20	Complete Schedule Equipment
	25	Additional Complete Schedule Equipment

The last step of the analysis involved a consideration of further modification and practical limitations to develop several alternative plant layouts. The new alternative plant layouts were designed and been evaluated and compared to the existing layout. The final layout was selected after the evaluation, providing a better plant space utilization, higher productivity, better flow of material and traffic flow and better safety and working condition.Assembly process for armored vehicle must obey the sequences of each installation. The step cannot simply bypass by other installation.

The assembly technicians are using work instructions that develop to follow the assembly sequence. All operations were conducted at all 6 stations. Sequences required are nominated as 710, 720, 760, 780, 930 and 991 respectively.Table 2.0 shows the details assembly activities list by station from the existing layout and current operation sequences. Before come out with several alternative layouts, firstly the practical limitation and modification consideration had to be identified and listed down. The reasons are to come up with the layout that meets the practical limitations and modification consideration. The existing layout as shown in Figure 3.0 was being studied and analyzed using SLP procedures. The practical limitation is a type of constraint that can disturb the flow of process in the plant layout. As a result, it can significantly affect the rate of productivity.

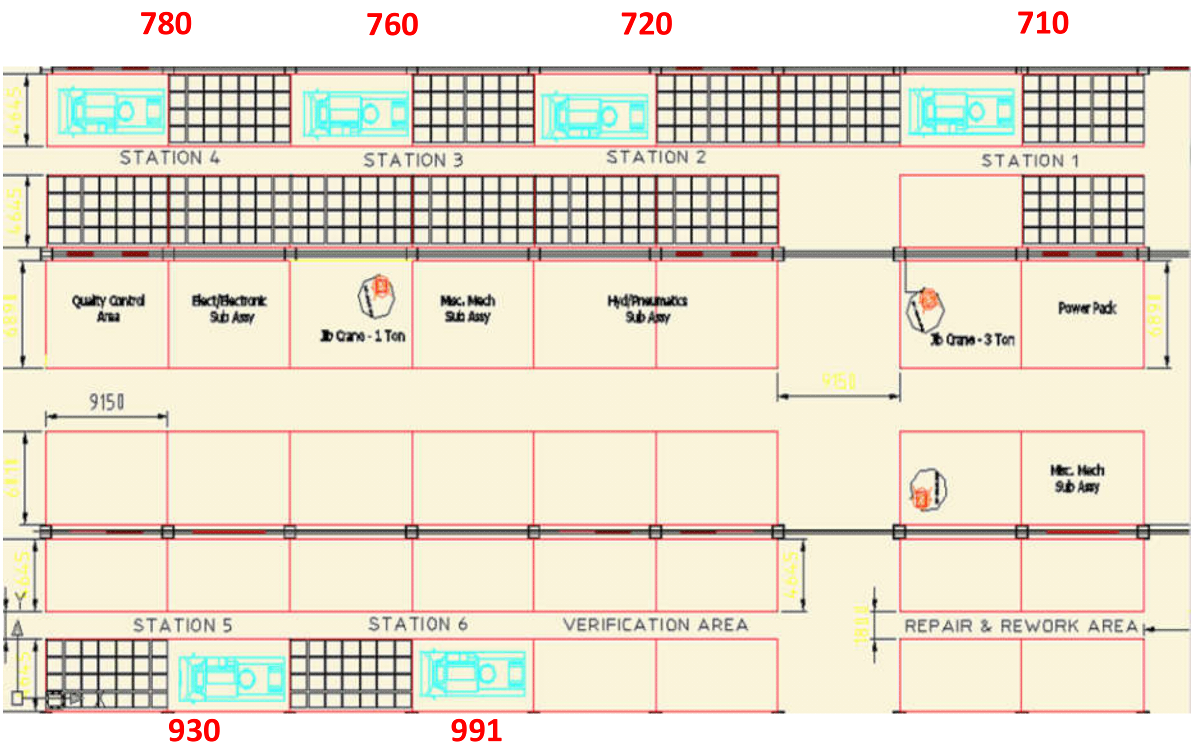

Figure 3. Existing Layout

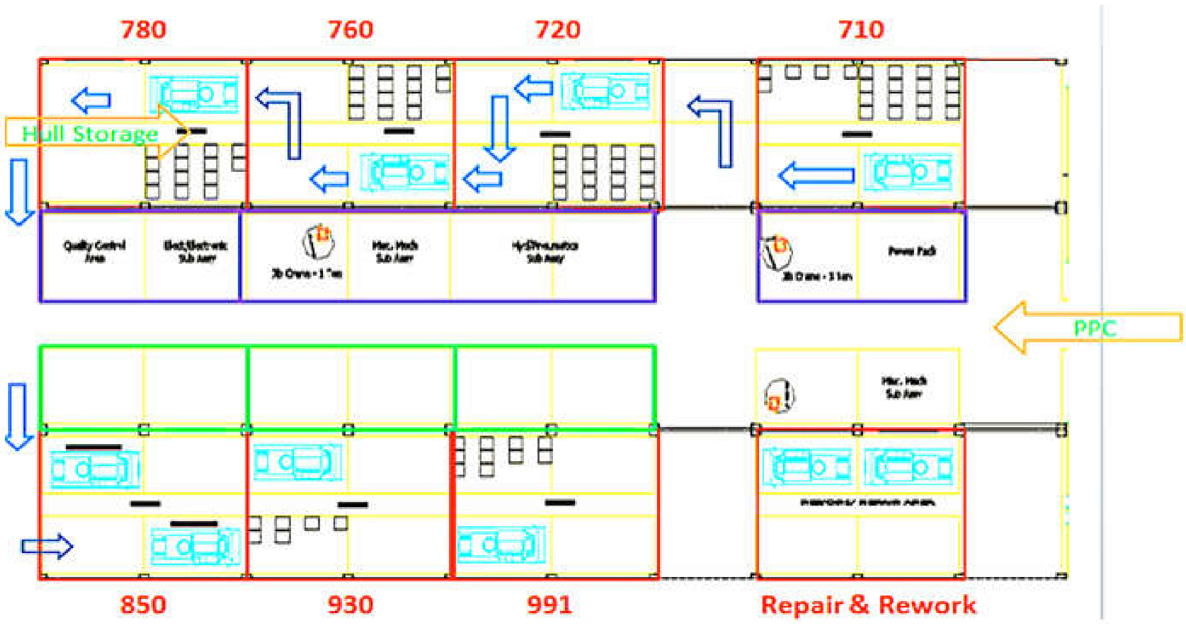

Figure 4. Alternative Layout 1

According to (Rajshekhar, 2010), the practical limitation could arise out of the space characteristic. The following are the practical limitation in the plant layout:

- The weight of the hull that make it harder to move. The empty hull weight is approximately 7 tones. It must be handled with care. It needs help of overhead crane to move from one station to other station until station 760.
- The hull can move after wheel installation completed at station 760. Then it needed to go through wheel alignment process.
- Special toolsare required for some installation. Special tools are the tools specifically designed and used to ease the installation of the armored vehicle. The installations that needed the help of special tools are: Suspension System, Transfer Case Installation, Drive Train Installation, Water Propulsion System, Wheel Installation, Armor Installation, Bumper Installation and Turret Installation.
- All stations required the help of overhead crane for certain installation. The installations that used overhead crane are Suspension System, Transfer Case Installation, Fuel System, Power pack Installation, Self-Recovery Winch, Winch Cover, Trim Vane, Grill, Ramp, Driver/Personal Hatch and Turret Installation.

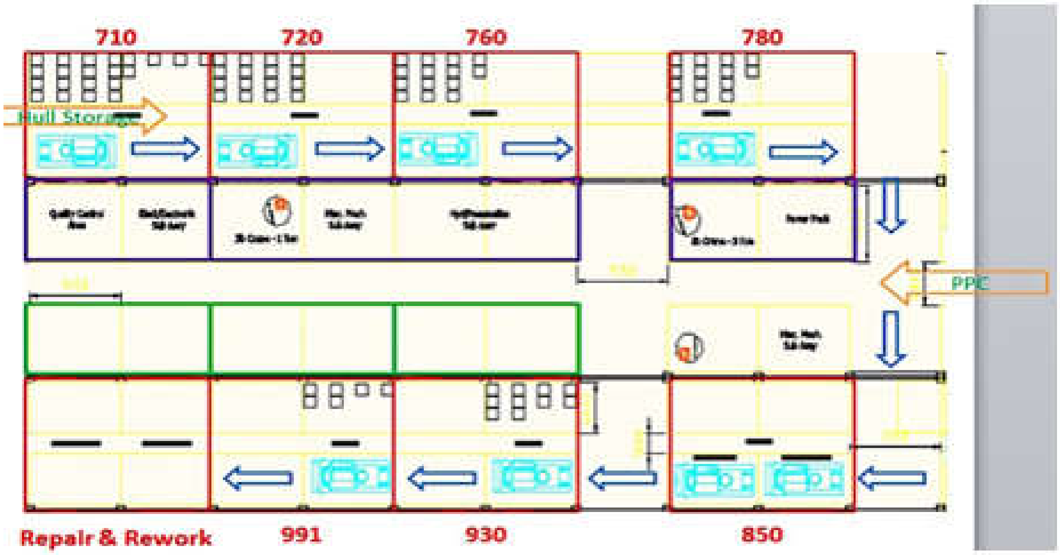

Figure 5. Alternative Layout 2

- Turret installation in station 930 required overhead crane with minimum height of 6m. The chain that is used to lift the turret must have a distance of 1m from the hook of the overhead crane to the turret.
- Jib crane. There are 3 x 1 ton jib cranes available in the plant layout which assisting the technicians to do their related task.

The modification considerations are

- Using Product layout type design. This layout type using the processing sequences for the part being produced on the line.
- Station 710 is the starting point of the assembly sequence. All the installation in this station needed to be installed first before others station's installation or it will cause problem and disturbed the flow of the installation.
- Safety's distance between the hulls must at least 2m.

As we can see above, Figure 4.0 and Figure 5.0 shows the Alternative Layout 1 and Alternative Layout 2 respectively.
The last step in SLP is to evaluate the best layout design among these designs. The advantages and disadvantages are defined in this step, which will be based on the performance of the assembly itself. There are 5 criteria that being analyze on each layout:

- Space utilize: The space used by the hull and part storage that used fully and efficiently
- Flow of material: The distance from Production Planning Control or Warehouse to production line
- Traffic flow: The distance from the part storage to the hull
- Preferred Closeness: The Arrangement of station or process that favored
- Safety & working condition: Safety of the worker and the situation that comfortable for the worker

Table 1.0 shows the summary of evaluated criteria from each layout, which was identified by their advantages and disadvantages.

Finally, the best layout recommended was Alternative layout 1, which best meets, all the criteria. The line balancing was conducted after SLP procedures, to level the workload across all process in assembly line to remove bottlenecks and excess capacity.

Table 1. Summary of comparison between existing and alternative layout

Criteria	Existing layout	Alternative layout 1	Alternative layout 2
Space Utilize	X	√	X
Flow of material	X	√	√
Traffic flow	X	√	X
Preferred closeness	X	√	√
Safety & working condition	X	√	X

Legend: X – Disadvantage;
√– Advantage

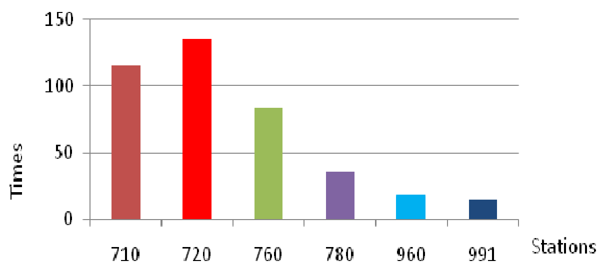

Figure 5. Takt time recorded before line balancing

Assembly line balancing method was proven by many case studies, which results in shorter physical line length and production space utilization improvement. This can be happened because the same number of workers can be allocated to fewer workstations as well as working load can be balanced accordingly. According to (Mahto, 2012), in order to increase the systems efficiency, eachstation must be equal workload in total or approximately the same. If the stations are unbalanced, inefficiencies in the form of idle timeor temporary blocking or starving of stations will be resulted. Before implementing the line balancing method, Takt Time has been recorded based on current assembly process on every single installation process.

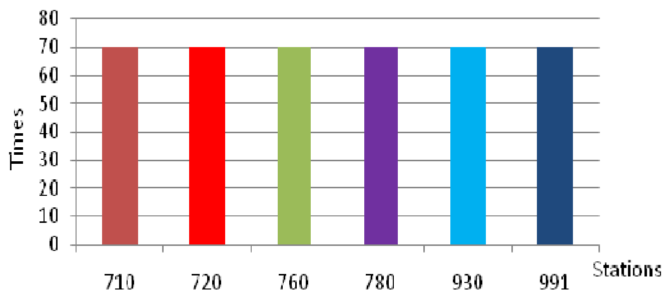

Figure 6. Takt times after line balancing

Table 3. The Summary of Line Balancing Calculations

Layouts' Name	Smoothness Index(SI)	Line Balance Efficiency,(E_b)	Balance delay,(d)
Existing Layout	115.67	35%	0.65
Alternative Layout 1 LCR Method	1.12	99%	0.01
Alternative Layout 1 KWM Method	1.82	99%	0.01

The Takt time data shows that the existing workload is not balanced and bottleneck occurred. Figure 5.0 and 6.0 can explain briefly comparison between current situation of 6 stations in assembly line before and after implementing the line balancing method. The total time taken to complete the assembly process is 417.78 hours. In order for the 6 stations to be balanced, the services time for each station must be 70 hours.Figure 5.0 shows that station 720 has the highest load followed by station 710,760,780,960 and 991 respectively. This situation shows that assembly technician in several station has overburden which leads to increase the waiting time for the next station. In order to resolve this issue, line balancing will be implemented.Figure 3.5 shows the result after the line balancing method was implemented. Based on Table 3.0, with SI 115.67,it can be concluded that the Existing Layout has a very bad workload distribution and very low efficiency. Existing Layout just achieved 35% Line Balance Efficiency,E_b and delayed, d about 65%.The Alternative Layout 1 proved by 2 Line Balance methods, LCR and KWM, shows that it has better SI, which are 1.12 and 1.82 respectively. Alternative Layout 1 achieved 99% Line Balance Efficiency,E_b and delayed, d about 1%. Therefore, the chosenAlternative Layout 1 proved it has a better efficiency compared to the Existing Layout.

Conclusion

Based on SLP and line balancing method that has been conducted, Existing Layout has shown very bad performance. Smoothness Index for existing layout is 115.67, which is very bad, and efficiency as low as 35%. Based on SLP procedures, 5 criteria were discussed in this research which are space utilize, flow of material, traffic flow, preferred closeness and safety and working condition. Alternative Layout 1 metall the criteria compared to Existing Layout and Alternative Layout 2. In addition, from Line balancing calculation, proven that alternative layout 1 also performed the best outcome, with Smoothness Index is 1.12 and 99% efficiency. Therefore, it can be concluded that Alternative Layout 1 is the best layout to be implemented. The improvement in layout efficiency will definitely increase the productivity as well as quality of the product. The project cost will be tremendously reduced due to very minimum part damage and waste because of waiting time.

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