Evaluation of Redesign Layout Using Discrete Event Simulation (DES)

Zakka Ugih Rizqi and Rachmat Aulia
Department of Industrial Engineering
Islamic University of Indonesia
Yogyakarta, Indonesia
16522252@students.uii.ac.id, 16522190@students.uii.ac.id

Abstract

KM ALUMUNIUM is one of the manufacturing company that produce household appliance such as frying pan and bread mold using aluminium as its basic material. KM ALUMUNIUM always producing every day following the customer order. According to the observation and interview result towards the owner and the workers, obtained that the facility layout on the shop floor is not good enough, it causes difficulty to the workers when doing material handling activities that makes productivity to becomes low. To redesign the facility layout, ARC (Activity Relationship Chart) and ARD (Activity Relationship Diagram) methods are used and it was implemented on computer simulation model using Flexsim 6.0 to see how much the improvement could be applied. It is obtained that the cause of bad facility layout is the finished warehouse location and finishing process location is not corresponding to the production flow so that it makes the frequency of workers delivering goods to be higher. By swapping the finished warehouse to the finishing process location and simulated for 1 workday, it is obtained that the material handling cost is reduced as many as 55,22% and the production output is increased by 25 products.

Keywords
Activity Relationship Chart (ARC), Activity Relationship Diagram (ARD), Material Handling, Simulation, Facility Layout

1. Introduction

According to the World Economic Forum (2017) report related to Global Competitiveness Index 2017-2018, Industrial Competitiveness in Indonesia ranked 36 from 137 nations, it could be improved by increasing the productivity of industry so that the company can compete. Efforts to increase productivity in manufacturing companies have many ways, one of the way is facility layout design.

According to Wignjosoebroto (2003), facility layout can be defined as the procedure for arranging factory facilities to support the smooth production process. The arrangement will utilize the area for the placement of machines or other production support facilities, the smooth movement of material, storage of material both temporary and permanent, workers and so on. The purpose of facility planning is to minimize material handling cost through effective regulation and coordination of physical facilities and to regulate safe and comfortable production operation facilities so as to increase performance of workers (Wignjosoebroto 2003).

KM ALUMINUM is one of the manufacturing companies engaged in manufacturing household appliances with a production base made of aluminium metal. The products produced are various but still within the scope of household appliances and the products most often ordered are pans and bread molds. The type of production used is make to order, where production is carried out if there are orders from customers. Every day, KM ALUMINUM always produces because of the many orders from customers, especially for pan and bread mold.

Based on the result of observation and interviews with the owner and workers of KM ALUMINUM, there were several problems including the distance of material movement between work stations which caused workers to get tired easily due to goods delivery activities without adding value to the product so that it also impacts on the amount of production costs caused by material handling and the amount of output produced, because 20-75% of production costs are caused by material handling (Tompkins et al. 2003). Therefore, redesigning the facility layout needs to be done on KM

ALUMINUM to rearrange material traffic lanes so as to minimize material handling cost and maximize the amount of output produced.

Based on the above problems, redesigning facility layout will be carried out using the Activity Relationship Chart (ARC) method to analyze the level of the relationship or the association of activities from a room to another room (Muther 1995). Then Activity Relationship Diagram (ARD) serves to represent the proposed layout after being analyzed using ARC which will be evaluated using a simulation with Flexsim 6.0 software so that it can be seen how far the improvement is. Simulation is the right tool to use if it is required to conduct experiments in order to find the best comments from system components (Muhammad 2010). The implementation of the simulation needs to be done because direct testing of the system will take considerable time and costs.

2. Method

The data are primary data that was obtained from observation and interview result from workers and manager of company. The data are used as input material for simulation model so that the model behaves like a real system, such as process time data, raw material arrival time data, number of machines and workers, and distance data between departments. Specifically for process data, the data is collected and then processed so that the process time distribution is obtained, this time distribution will be used in the simulation model so that the model is made in accordance with the actual system. Because in reality, no workers work with the same processing time, surely there is always a difference. For the methodology scheme can be seen in the flowchart below.

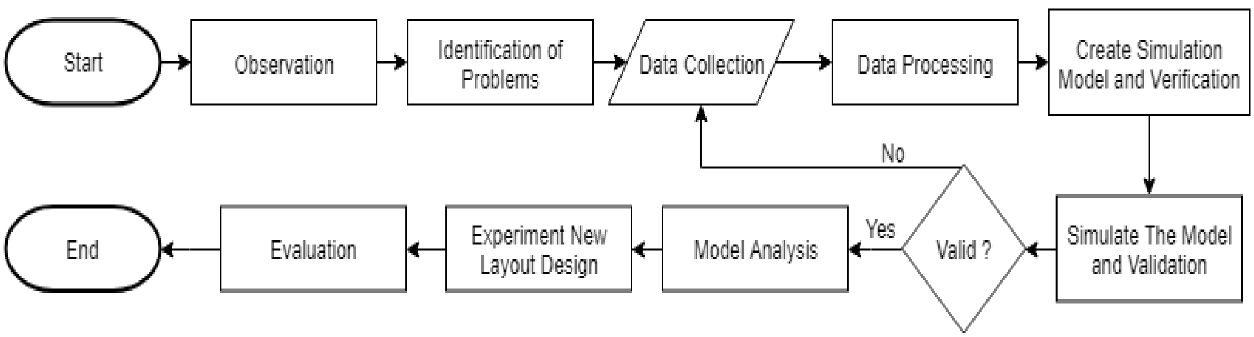

Figure 1. Flowchart of the methodology

After the simulation model has been successfully created and verified, the next step is to simulate the model and then validate using nonparametric statistics to test whether the model created behaves like a real system or not. The manner in which a model is implemented determines the range and level of outputs that can be used in the validation and final analysis (Karnon 2012). The Chi-Square test will be used as a validity test by comparing the simulation output with the company's historical output. After the model is declared valid, then the researcher can analyze the model followed by conducting experiments on the solutions that have been obtained and ended with an evaluation of the experiment.

2.1 Object of Research

In this study, the object of the research was production floor at KM ALUMINIUM Yogyakarta, which is one of the manufacturing companies with the main production base of aluminum metal. KM ALUMINIUM has 16 workers, which are divided into 1 worker in the aluminum smelting process, 5 workers in sand molding for bread mold product, 2 workers in metal molding for pan product, 4 workers in finishing process and 4 workers in polishing process. Researchers focus on production process of pan and bread mold, because those products are often ordered. The production process flow and initial layout of KM ALUMINIUM can be seen in the figure below.

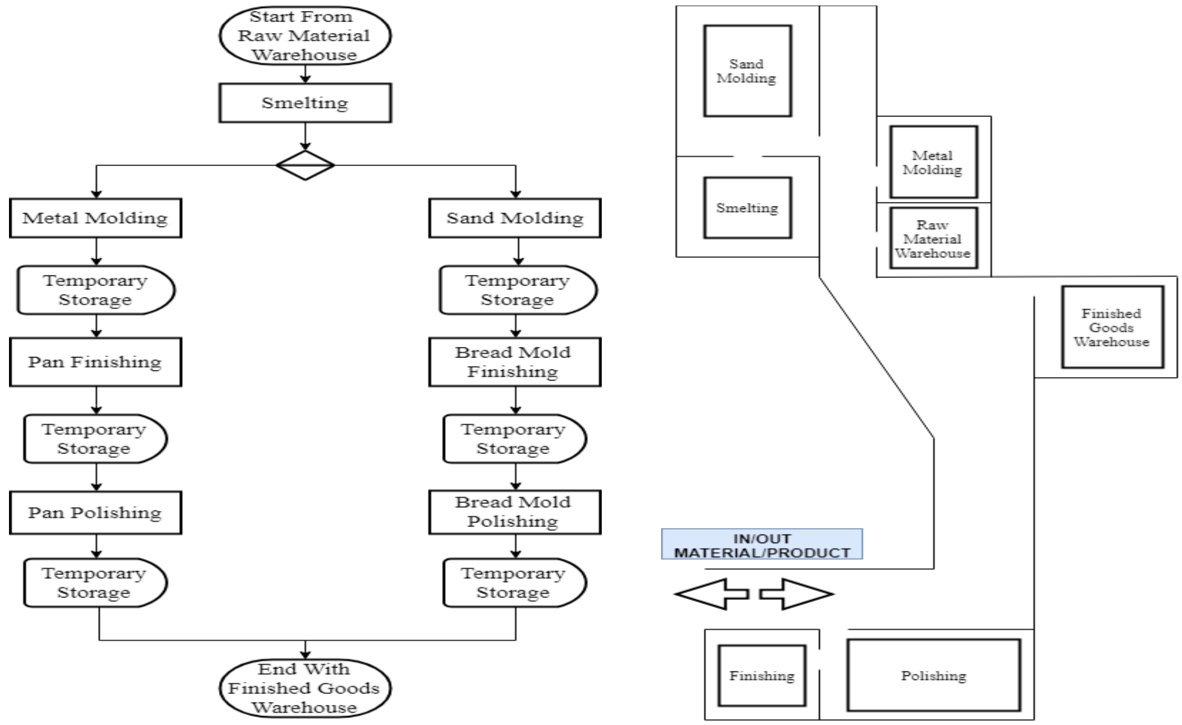

Figure 2. Flowchart of production process and initial layout

The large of location for each department needs to be known as consideration in conducting ARC analysis. Location exchange can also be done if the difference in large is not significantly different.

Table 1. The large of location for each department

No	Location	Large
1	Raw Material Warehouse	6 m^2
2	Smelting	12,25 m^2
3	Metal Molding	15 m^2
4	Sand Molding	21 m^2
5	*Finishing*	18 m^2
6	*Polishing*	40 m^2
7	Finished Goods Warehouse	15 m^2

2.2 Discrete Event Simulation (DES) and Flexsim

Discrete event simulation (DES) is a flexible modeling method characterized by the ability to represent complex behavior within, and interactions between individuals, populations, and their environments (Pidd 2004). Simulation is a technique that mimics operations or processes that occur in a system with the help of computer devices and based on certain assumptions so that the system can be studied scientifically (Law and Kelton 1991).

Flexsim simulation software is developed and owned by Flexsim Software Products, Inc. of Orem, Utah (Nordgren 2003). Flexsim is a discrete-event, object-oriented simulator developed in C++, using Open GL technology. Animation can be shown in tree view, 2-D, 3-D, and virtual reality. Flexsim is used to improve production efficiencies and reduce operating costs through simulation, experimentation, and optimization of dynamic flow systems. Engineers and managers use Flexsim to evaluate plant capacity, balance packaging and manufacturing lines, manage bottlenecks, solve work-in-process problems, justify capital expenditures, plan equipment maintenance schedules, establish proper inventory levels, improve order-picking systems, and optimize production rates (Banks 2005).

3. Result and Discussion

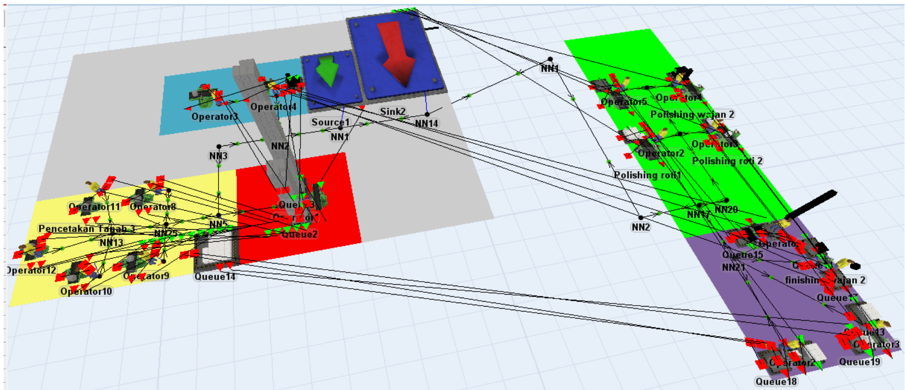

Figure 3. Initial model layout in flexsim

After the model is constructed, then the credibility will be enhanced by performing the validation. Validation process will apply Chi-Square test to assess whether the resulted of simulation model will have the fitness with observed real system.

1. Form of Hypothesis
   H0 : There is no difference between the frequency of simulation data and the frequency of historical data.
   H1 : There is a difference between the frequency of simulation data and the frequency of historical data.
2. Acception Area
   Using probability alpha = 0.05 with the number of data n-1 (30-1=29). By looking at the Chi-Square table the value of $\chi 2$ table is 42.55 as the limit.
3. Calculating Testers Statistics
   The data that will be used for the Chi-Square test is simulation output data (Oi) for 1 working day as many as 30 data compared to 30 company historical data (Ei) that is expected.

Table 2. Historical output data and simulation

Day	Oi	Ei	$\frac{((Oi-Ei)^2)}{Ei}$	**Day**	Oi	Ei	$\frac{((Oi-Ei)^2)}{Ei}$
1	513	521	0.12	**16**	512	505	0.10
2	514	507	0.10	**17**	513	512	0.00
3	515	513	0.01	**18**	513	521	0.12
4	515	516	0.00	**19**	510	506	0.03
5	513	505	0.13	**20**	517	515	0.01
6	511	507	0.03	**21**	512	519	0.09
7	515	508	0.10	**22**	514	513	0.00
8	519	508	0.24	**23**	514	515	0.00
9	517	506	0.24	**24**	510	506	0.03
10	515	506	0.16	**25**	516	510	0.07
11	514	520	0.07	**26**	515	514	0.00
12	515	513	0.01	**27**	512	509	0.02
13	510	515	0.05	**28**	513	514	0.00
14	513	511	0.01	**29**	511	507	0.03
15	512	521	0.16	**30**	514	517	0.02

With the formula :
$\chi 2$ calculated = $\Sigma(Oi - Ei)^2/Ei$, the value of $\chi 2$ calculated = 1.94 is obtained.

4. Making Decision
If $\chi 2$ calculated < $\chi 2$ Table, H0 is received.
If $\chi 2$ calculated > $\chi 2$ Table, H0 is denied.
Because $\chi 2$ calculated = 1.94 which is less than $\chi 2$ table = 42.55, so that H0 is received. It means There is no difference between the frequency of simulation data and the frequency of historical data. In other words, the simulation model can be used as a reference for analysis and improvement.

3.1 Analysis Initial Layout

Based on the initial layout simulation that has been made, measurement of material handling cost can be done using Flexsim tools so that it does not need to be calculated manually, by including costs for travel empty and travel loaded operators in Flexsim 6.0 which are assumed to be 1 dollar with fix value 1 dollar. From simulation that has been carried out, obtained material handling cost as shown below.

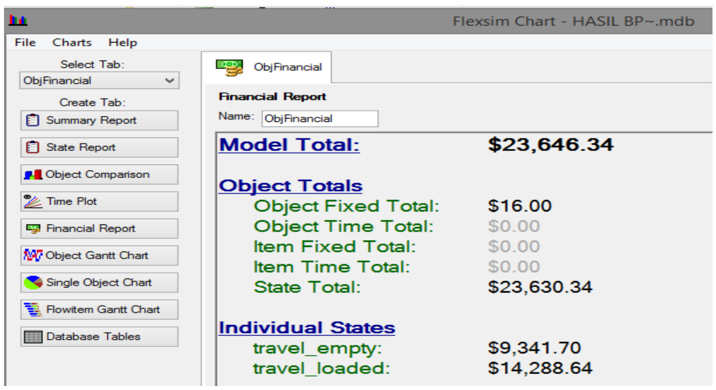

Figure 4. Material handling cost in initial layout

It can be seen that material handling cost in the initial model was $ 23,646.34. That value will be a parameter of success from the redesign layout, whether material handling costs are decreasing or not. In addition, there were also 515 products produced by the company (480 products are already in the finished warehouse, while 35 products are still in the temporary storage that have not been delivered to the finished warehouse).

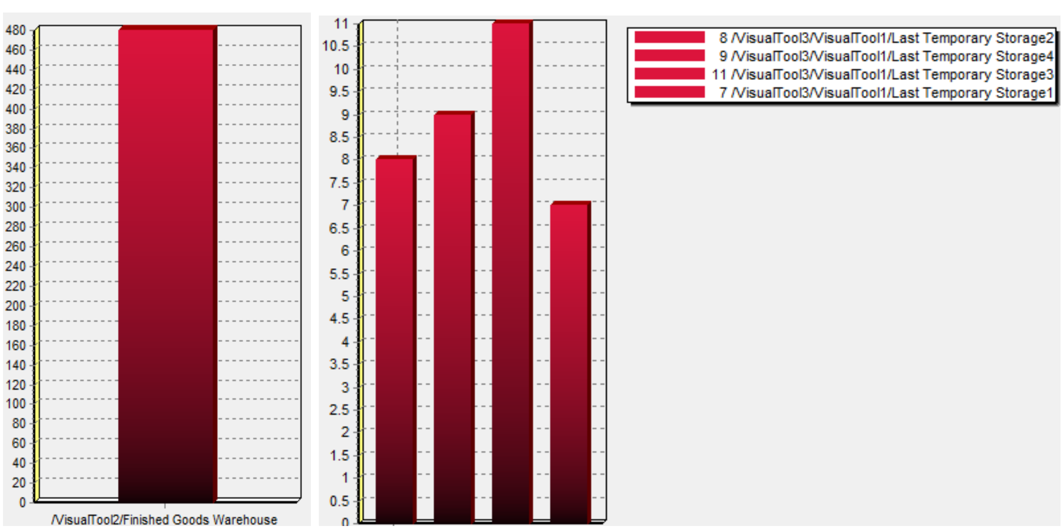

Figure 5. The number of products produced in the initial layout

3.2 ARC and ARD Analysis

Activity Relationship Chart (ARC) analysis is done by considering the opinions of the company owner. ARC analysis with the information of reasons can be seen in the figure below.

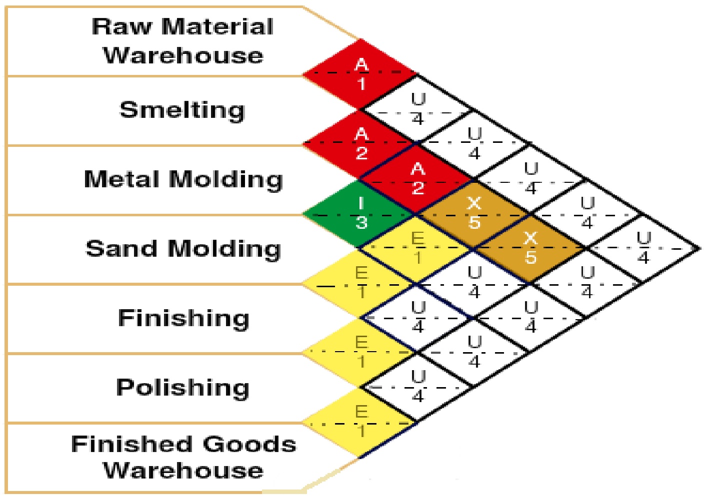

Figure 6. Activity relationship chart

Table 3. Information of ARC

No	Level of Importance	Code	Color
1	Absolutely Important	A	Red
2	Very Important	E	Yellow
3	Important	I	Green
4	Usual	O	Blue
5	Not Important	U	White
6	Undesirable	X	Brown

Table 4. Description of reasons

Code of Reason	Description of Reason
1	Smoothness Material Flow
2	The Amount of Risk
3	Material Similarity
4	Has No Functional Relationship

Based on the Activity Relationship Chart and considering the large of each department, exchanging the finishing workstation with the finished warehouse is a change in layout that can be applied. The reason is because of incompatibility between the finished warehouse and the finishing process with the production flow which causes workers to carry things back and forth (backtracking) and ultimately increase material handling costs. So that in this study, researcher will try to swap between the location of the finished warehouse and the finishing process.

Large differences in the finished warehouse (15m^2) and in the finishing process (18m^2), there is a difference of 3m^2, if the location is exchanged it will not be a problem. Because the finishing process does not require a large area where only the gerindra tool is used and there is still a large enough space left. In addition, the finished warehouse is only a small shelf so it is easy to move. Therefore, exchanging these two locations is very possible and does not cause new problems.

After analyzing ARC, ARD can be made as a proposed layout which can be seen in the following figure along with an explanation of ARD (number in figure 7 according to the number in table 1 and code in table 5 according to the code in table 3).

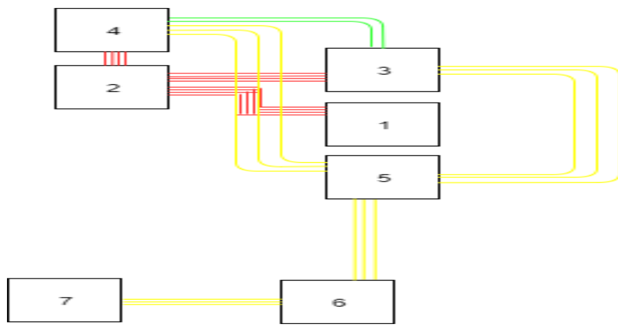

Figure 7. ARD proposed layout

Table 5. Explanation of lines and colors in ARD

Line & Color	Code
	A
	E
	I
	O
	U
	X

3.3 Comparative Analysis of Initial Layout and Proposed Layout

The following is the proposed model based on ARC and ARD, where the location of the finished warehouse is exchanged for finishing process.

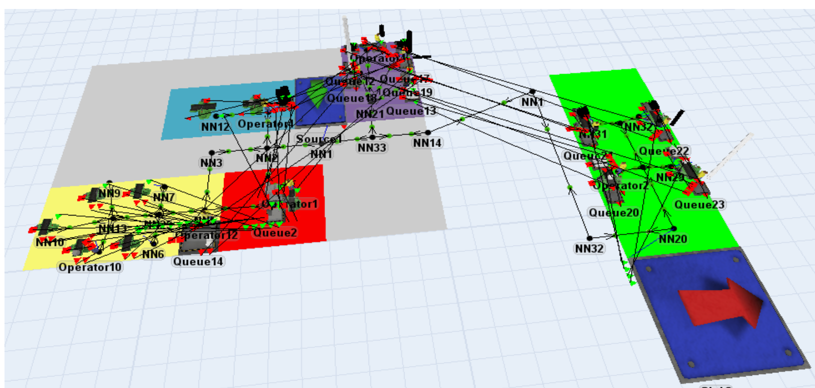

Figure 8. Proposed layout of KM ALUMINIUM

From the proposed layout, the simulation is done again for 1 working day and the material handling cost are obtained which are smaller than the initial layout.

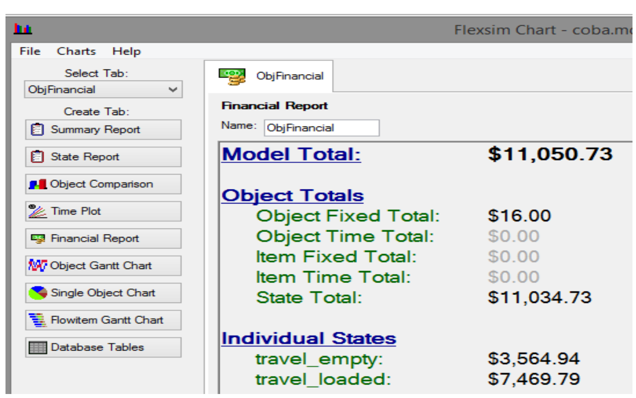

Figure 9. Material handling cost in proposed layout

It can be seen that the material handling cost is decreased from \$ 23,646.34 to \$ 11,060.73 so that the decline was \$ 12,585.61 or 55.22%. In addition, the proposed layout is also able to make production output increase to 540 (520 products are already in the finished warehouse, while 20 products are still in the temporary storage that have not been delivered to the finished warehouse) which was originally 515 (increased by 25 products).

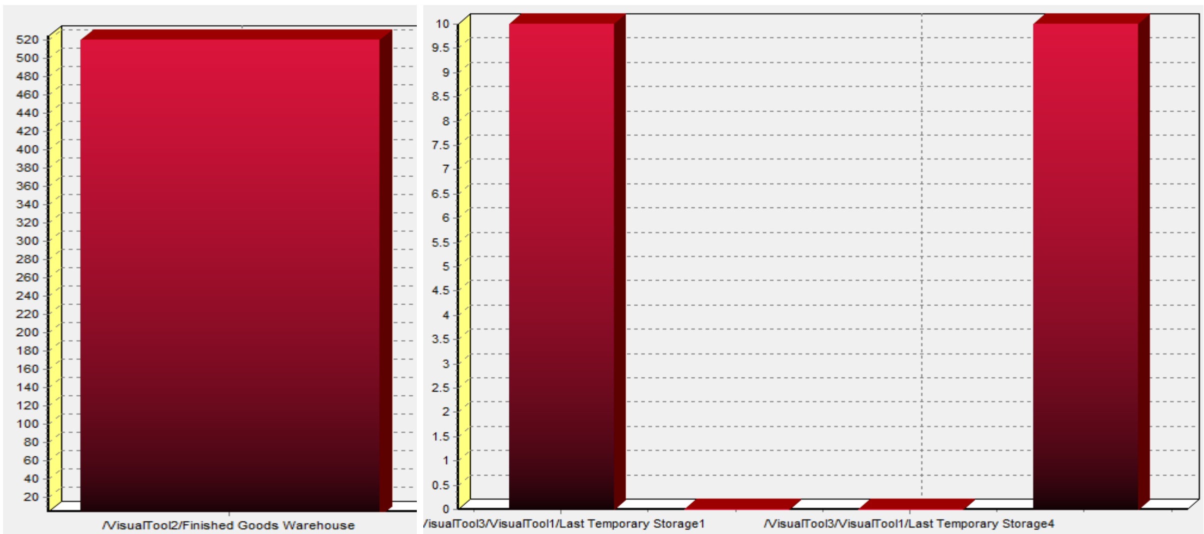

Figure 10. The number of products produced in the proposed layout

4. Conclusion

The conclusion of this study is that poor layout causes high material handling costs which means high frequency of workers in delivering goods. The cause of poor layout in KM ALUMINIUM is that the location of finished warehouse and finishing process does not match with the production flow causing high frequency of workers in delivering goods (backtracking), this is also included excessive transportation waste in lean manufacturing concepts that must be eliminated. By exchanging the location of the finished warehouse with the finishing process, the material handling cost changed from \$23,646.34 to \$11,060.73 so that the decrease was \$12,585.61 or as much as 55.22%. In addition, there was also an increase in output of 25 products, which initially 515 products became 540 products.

References

Banks, J., John, S., C., and Barry L., N., *Discrete-Event System Simulation*, 4th Edition, Upper Saddle River, N.J.: Prentice Hall, 2005.

Karnon, J., Modeling using Discrete Event Simulation, *A Report of the ISPOR-SMDM*, Value In Health, 2012.

Law, A.M., and Kelton, W.D., *Simulation Modelling and Analysis*. 2nd Edition, McGraw-Hill, New York, 1991.

Muhammad, *Perancangan Permainan Simulasi Bisnis Pada Perusahaan Shuttlecock Sebagai Alat Bantu Praktikum Perancangan Teknik Industri*. Surakarta, Universitas Sebelas Maret, 2010.

Muther, R., *Practical Plant Layout*, 1st Edition. Mc Graw-Hill Book Company, Inc, New York, 1995.

Nordgren, W. B., Flexsim Simulation Environment, *Proceedings of the 2003 Winter Simulatwn Conference*, S. Chick, P. J. Sanchez, D. Ferrin, and D. 1. Morrice, eds., New Orleans, LA, Dec. 7-10, pp. 197-200, 2003.

Pidd, M., *Computer Simulation in Management Science*, 5th Edition, John Wiley & Sons, 2004.

Tompkins J.A., White J.A., and Bozer, Tanchoco J.M.A., *Facilities Planning*, 3rd Edition, John Willey & Sons, Inc, California, 2003.

Wignjosoebroto, S., *Ergonomi Studi Gerak dan Waktu*, 1st Edition, Guna Widya, Jakarta, 2003.

World Economic Forum, The Global Competitiveness Report 2017-2018, Available: https://www.weforum.org/reports/the-global-competitiveness-report-2017-2018, September 26, 2017.

Biographies

Zakka Ugih Rizqi is an Industrial Engineering student in the Islamic University of Indonesia, Department of Industrial Engineering. He is an undergraduate student and has a great grade in his university. His research interests include simulation, optimization, and project management. He also works as a laboratory assistant of industrial modelling and simulation in Islamic University of Indonesia. He also actives in the competition of industrial engineering and in the conference as a presenter.

Rachmat Aulia is a student of Industrial Engineering in the Islamic University of Indonesia, Department of Industrial Engineering. He also works as a laboratory assistant of Enterprise Resource Planning (ERP) in Islamic University of Indonesia. He is aslo known for his good public speaking skills. His research interests include Supply Chain Management, Enterprise Resource Planning (ERP), and Logistic Management.