

Design and simulation of integration system between automated material handling system and manufacturing layout in the automotive assembly line

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Abstract. Material handling system (MHS) is an important part for the productivity plant and has recognized as an integral part of today's manufacturing system. Currently, MHS has growth tremendously with its technology and equipment type. Based on the case study observation, the issue involving material handling system contribute to the reduction of production efficiency. This paper aims to propose a new design of integration between material handling and manufacturing layout by investigating the influences of layout and material handling system. A method approach tool using Delmia Quest software is introduced and the simulation result is used to assess the influences of the integration between material handling system and manufacturing layout in the performance of automotive assembly line. The result show, the production of assembly line output increases more than 31% from the current system. The source throughput rate average value went up to 252 units per working hour in model 3 and show the effectiveness of the pick-to-light system as efficient storage equipment. Thus, overall result shows, the application of AGV and the pick-to-light system gave a large significant effect in the automotive assembly line. Moreover, the change of layout also shows a large significant improvement to the performance.

1. Introduction

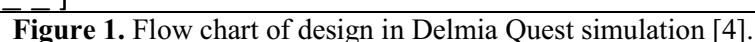
In a typical factory, material handling consists of 87% production time and an average of 50% total cost for company operation in manufacturing product [1, 2]. Hereby, material handling system is important in facilitating production layout. It has been several years that material handling has become a new and rapidly evolving science, hence a proper design of material handling system is important to facilitate worker safety and make the production and process flow become more efficient. A problem gap can be seen through an observation of case study at a selected real automotive assembly line, mainly in the material handling equipment or the layout facility that integrate material supply in the production line with inventory system in the warehouse.

Based on the case study observation which is done in an actual factory, the production background is start with logistic warehouse, body shop, paint shop and lastly assembly shop where the painted body is assembled in three main stations. The issues involving material handling can contribute to the reduction of production efficiency where the time required for an operator to do work is wasted. This research work focused on one main station only where one type of car is assembled. The semi-auto



This paper intends to show the influences of material handling system and layout of material flow in an automotive assembly line by simulating the system in Delmia Quest software. The equipment focused on this research work is transport and storage equipment, where the new proposed system is compared with the simulation of the current system in a real situation of automotive assembly line factory. The improvement is done involving changes of transport equipment from manual tugger train into Automated Guided Vehicles (AGVs), and the changes of current storage equipment using manual order from the assembly line into semi-automatic order of the pick-to-light system in the warehouse. Therefore, a simulation of the automotive assembly line that is comparable to the case study on the real factory is done through simulation and the process performance is analyzed.

This section explained the data gathering needed for the simulation. All the data is taken from a case study done in one of the automotive factories in Malaysia and the data is gathered from observation, parts borrowing and reading on existing documentation. The process flow in designing the system, as shown in Figure 1 is started with planning, where all the data gathered in arrangement based on the elements needed in Delmia Quest software [4]. It consists of plant layout from warehouse to assembly line, distance traveled, distance between each station, including all parts involves in the process and their handling flow, and lastly is the transportation used to transfer part from warehouse to assembly line.



Starting from warehouse system, the error in parts arrangement cause improper part supply system. There is a possibility that operator might mistakenly sent parts to the carrier on the assembly line. Downline on the assembly line is caused by parts provision. This is because the manual system that used the list on paper can cause a human error in ordering parts. Thus, a pick-to-light system is recommended in this research work. Another issue is that, after in-depth observation and interview with operator and line captain, it is found that the operator in assembly line needs to walk and take the cart that supply from the supermarket and transfer the parts into assembly line. In the system level design, all the data planned is transfer into simulation elements. The model 1 is done similar to the case study situation, where the result of the model 1 is referred as the base performance of the current system to compare with other models. There are 3 models overall that are proposed for this research, All the design undergo evaluation test by comparing their production status and cycle time value with the current system values. Later on, the validation process is done by observing that all the components used are working properly and satisfied the current system requirement.

The factors considered in the experiment are type of layout, transport equipment, and storage equipment. Table 1 illustrates the variation of factors used for the experiments. Noted, that model 1 is the similar process used in the case study factory. The purpose of model 2 creation is to study the influence of material handling in the system. Meanwhile, model 3 brings the purposes of studying the new layout effect together with the improved material handling to the system performance. The comparison between all models can be used to analyze the significant effect of improving material handling and layout to the system. The comparisons between all models also act as a validation of the design capability to function similarly like the real situation of the factory.

Table 1. Variation of factors and list of models.

Models	MHS Configuration		
	Layout	Transport equipment	Storage equipment
Model 1	Old layout	Tugger train	Picking list system
Model 2		AGV	Pick-to-light system
Model 3	New layout	AGV	Pick-to-light system

In order to familiarize with the assembly line of the case study, observations and studies on all related documentations are done. The current layout of the assembly line is called old layout as shown in Figure 2 which state the transportation track from warehouse to assembly line including the travel distance. This research work only focuses on chassis line which consists of 1 transport pick-up station at the warehouse with 7 sub-pick-up stations where the labor is assigned to collect all the parts and load it into transportation. Also, the old layout has 10 drop off stations with different processes and part supplies. In the assembly line, each process has their own stations and each station is not fixed with only one process. It involves assembly of 3 to 4 types of different parts for each station.

The differences between current layout and proposed layout are the stations and the distance travel. Figure 3 shows the layout of the new system. It is based on the cellular and product layout concept, in which the concept is easier to monitor, easy to automate and most important it can increase the flexibility of the system [5, 6]. The new layout is designed in concerned of the design of the rack used as temporary storage while parts are transferred, and the allocation of each process is suited with the chassis line. As mention previously, the new layout consists of only 7 pick-up stations and 8 drop-off stations. Even though the stations have been reduced, the processes of the new system are the same with the current assembly processes due to a combination of 2 stations into 1 station.

Basically, the travel distance is according to movement of transportation from pick-up point at the warehouse and return back to its starting point in order to have a total distance traveled in 1 cycle of working hour. Apart from familiarizing with the assembly line, all parts involve have also been studied in order to know the requirement for parts distribution for every stations. All 31 parts are required for the assembly process of one type of car model. In order to avoid confusion and keep focusing on answering the research question, only one model of assembled car is focused.

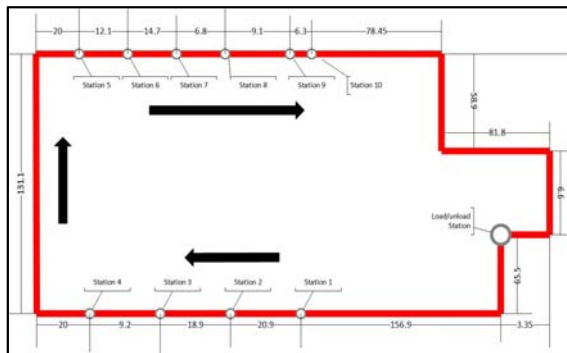


Figure 2. The drawing of old layout

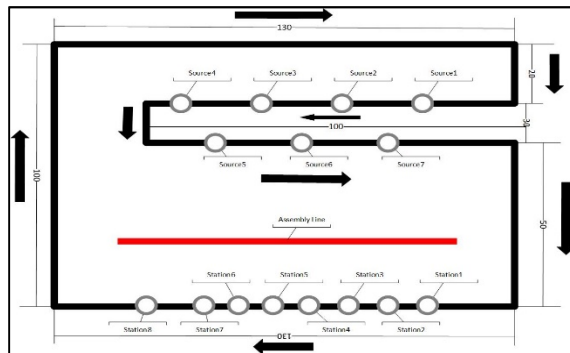


Figure 3. The drawing of new layout

In the case study, a fixed space for location of production and storage has been decided. Thus, on-floor transport equipment is the best recommendation to improve the system. AGV is introduced to replace the current tugger train transportation. Meanwhile, multiple parts are stored in different sections where the warehouse has already divided the parts into racks. The current warehouse system used in the case study is manual order picking list coming from the assembly line. A pick-to-light system is introduced to change the system into semi-automatic in the warehouse, and the order has been already programmed into the rack itself.

3. Simulation using Delmia Quest software

Delmia Quest includes various elements consist of physical model, parts, modeling element, logic and connections that justify parts flow through the model. This section discusses all elements needed to design the simulation. Delmia Quest is different from simple CAD approach in laying facility, where various parts and elements have interaction and logic between them. Even though the development of simulation is in sequence, but the order is not rigid as each step must be completed before simulating the model.

3.1. Elements in Delmia Quest

The layout arrangement consists of few elements in Delmia Quest software, which are parts as the main element, sources as the parts creation element, buffer function as the parts storage element, and lastly, the material handling elements (Labour, AGV, tugger train, picking list and pick-to-light).

Creating parts in the model is compulsory, in order to represent the models. No matter what kind of parts, they are the entities in Delmia Quest model that flow through the system, occupying resources and undergoing processing. Thus, when parts are created, source is made to produce the parts to allow other elements for processing and consumption. The source is very flexible elements that represent the entry-point of parts into the model. All models for this research work are using the same character of sources, but with a different arrangement of the layout based on the previous Figure 2 and 3. The label of the source also describe for parts arrangement for bins in the warehouse, the destination of the parts is set using simulation control language to assign a different quantity of parts for every sources. All models have 7 sources for storage elements in the warehouse. Meanwhile, 1 additional source is created at assembly line to resemble the arrival of car's frame into the conveyor to be assembled by labor.

Based on case study situation, transport equipment transfer parts using bins containing different parts based on workstations in the assembly line. The bins later are loaded into transportation and being transferred to the assembly line. This is where the function of buffers element is used, to represent temporary storage locations for parts before labor or transportation pick up the parts for next process. The function of the buffer at the warehouse is as hopper where the labor pick up a group of different parts that coming from the source and collect them into bins. Same as buffer at the assembly line, parts are stored in the buffer until labor pick up parts to do assembly work. The list of sources and buffers are described in Table 2 according to each model.

Table 2. List of sources and buffers for every model

Models	Sources	Warehouse's Buffers	Assembly's Buffers
Model 1		OPT1_Buffer_1 OPT1_Buffer_2	Assembly_Line_Buffer, α (α : 1 to 10)
Model 2	Main_Car	OPT2_Buffer_1	
	Source_OPT1	OPT2_Buffer_2	
	Source_OPT2	OPT3_Buffer_1	
	Source_OPT3	OPT3_Buffer_2	Assembly_Line_Buffer, α (α : 1 to 8)
	Source_OPT4	OPT4_Buffer_1	
Model 3	Source_RC_Bin	OPT4_Buffer_2	
	Source_RR_Centre_Bracket	Dash_Buffer_1	
		Dash_Buffer_2	
		RC_Buffer_1	
		RC_Buffer_1	

Queuing discipline applied in all models is First-In-First-Out (FIFO), based on the concept where every time the buffer at assembly line is free, a new part will enter. Thus, a system where the first part to enter the buffer will be the first to be routed out is created. In Quest, transport and labor elements, loading and unloading parts at a decision point where the parts from other elements may enter and exit the path system only through the decision point.

In addition, traffic management of AGVs' and trains' stopping point is also at the decision point. In this research work, the decision point for AGV and train is divided into 2 sections that cover the 3 models used in the experiment. Section 1 consist of model 1 where their path system and decision point is created similar with case study's transportation path system. For model 2 and 3, the path system is a bit different due to the application of the pick-to-light system in the warehouse. The number of decision point for model 1 is 10 points at assembly line and functions as the parts drop off stations and 1 decision point for AGV pick-up station. Not forgetting, 7 decision points for labor inside the warehouse. As for model 2, the quantity of decision point is the same as model 1 at assembly line and has 7 decision points for tugger train at the warehouse.

In Quest, the user can set minimum requirements that need to be satisfied for the AGV, train or labor to leave the decision point. This setting is defined in depart requirement button. Until the requirement is satisfied, the AGV, train or labor will wait at the decision point, and unable to move. But it is restricted that the departure requirement will not be set to a value greater than the capacity of the AGV, if not the AGV will never move from the decision point.

The entry of parts is coming from the 7 sources as shown in the previous topic. In order to make the model realistic and as close to the actual process as possible, every time source detects zero queues (empty) at buffer, a part will be released from the source. It shows that the source monitors the buffer that is the first station in the production sequence of each part. Also, in order to show the uniqueness of the designed and determination of the outline structure in a fabrication of manufacturing layout, a Simulation Control Language (SCL) is applied in part entry of the model. SCL is used only in source and buffer process in order to have a unique sequence of part allocations in warehouse and assembly line.

3.2. Running simulation

The simulation can run after all elements are in place and connected with each other. The finished layout is illustrated in Figure 4 (model 1), Figure 5 (model 2) and Figure 6 (model 3) respectively. Each source for all models has 2 buffers together colored as purple in the Figures and the pickup station is at the center of the warehouse, allocate together with labor. The buffers at the assembly line are shown as cyan in the Figure. The characteristic of all models for warehouse buffers and assembly line buffers are using the default setting from Quest software.

The simulation is run with working day starting from 8.00 a.m. until 5.00 p.m. (8 hours). The 1 hour time is given as a rest time for labor. The result taken is only for 1 day of working time. The amount of time the labors take to transfer part between each assigned stations is established at 10 seconds of constant on the contribution.

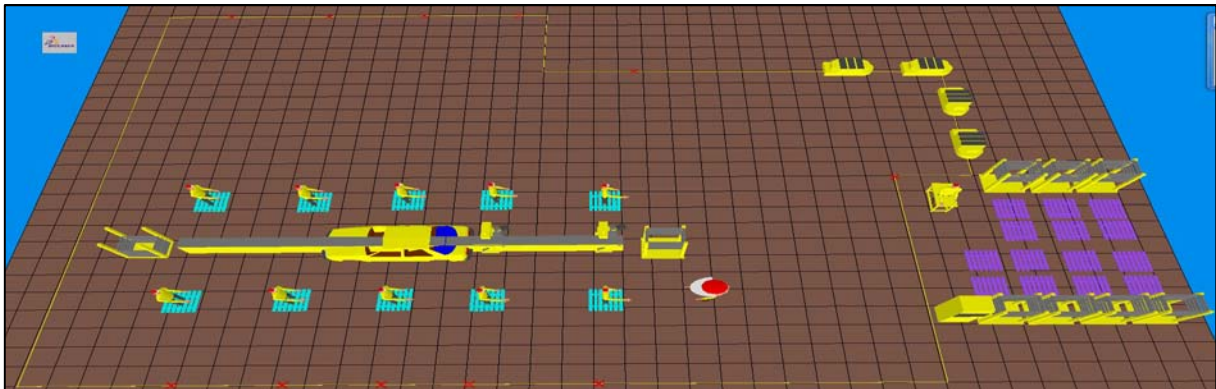


Figure 4. The layout for model 1

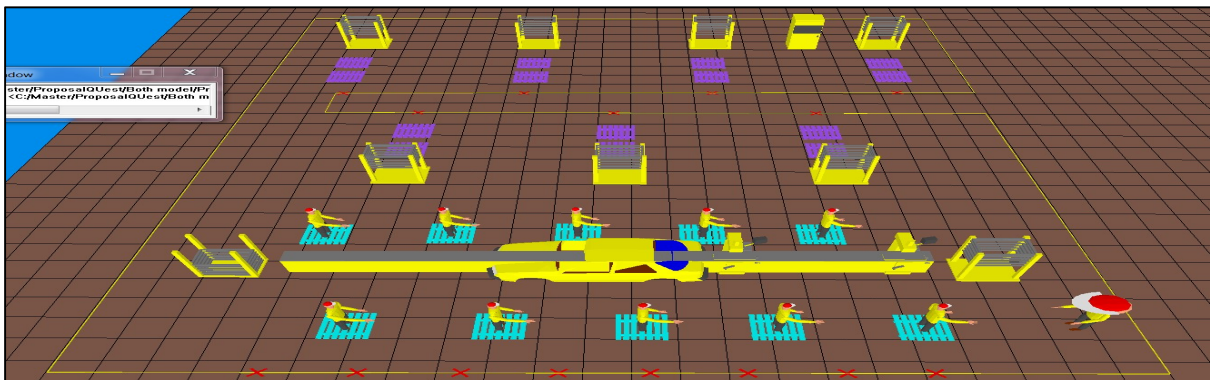


Figure 5. The layout for model 2

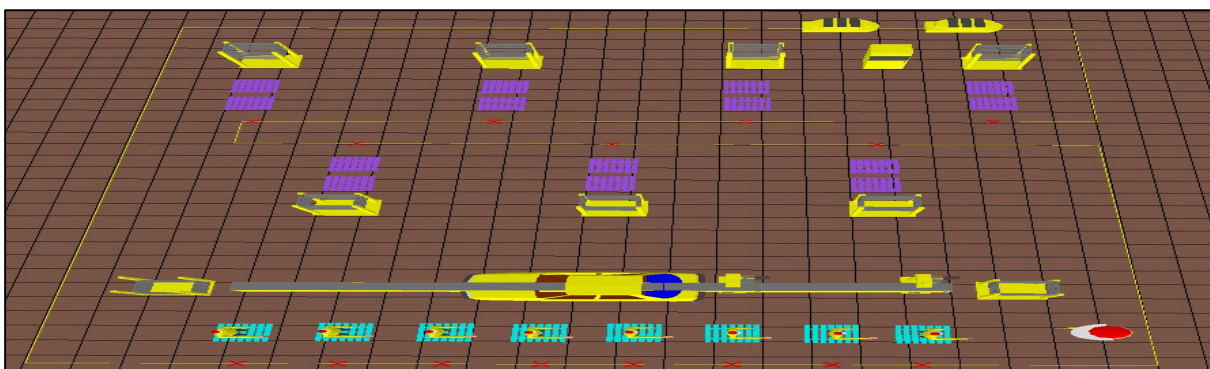


Figure 6. The layout for model 3

4. Improvement result of automotive assembly line performance

The result is compiled and presented in the statistical chart that consists of a few elements such as element class statistic (the total part created and the number of part supply), throughput rate in source statistic, the utilization of transportation statistic, the idle time and part entries of drop off buffer statistic and lastly a comparison of work in process for every models.

Based on the simulation result, the output increased sharply over the period where the output for a complete assembled car for the current system in model 1 is 14 units per working hour. The pie chart in Figure 7 illustrates the output (total part created), nearly half of the chart conquered by model 3's

output. After changes of transport and storage equipment, the output increase as much as 36 units per working hour. When the layout is improved in model 3 the output increase 31% from the output of model 2, make the unit production is 47 units per working hour. It is obvious that the increment of output from the pie chart of Figure 7 is due to the effective material handling using AGV and pick-to-light system in the factory and the changes of the layout give more significant effect in the system.

Total Number of Parts Delivered Between All Models

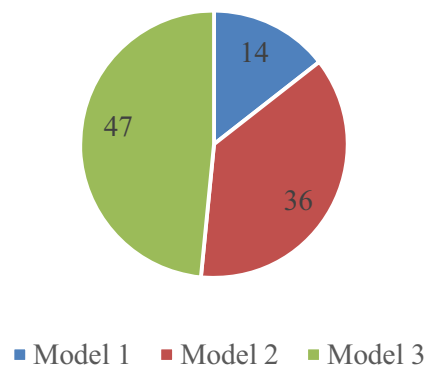


Figure 7. The pie chart of total number of parts delivered between all models

Figure 8 is the chart area that illustrates the throughput rate of the source in the warehouse. From model 1 to model 3, the chart shows remarkable changes of the area. That is most likely due to the total throughput rate data rose from only 53 units per working hour in model 1 status into 180 units per working hour in model 2. The source throughput rate average value went up into 252 units per working hour in model 3 and shows the effectiveness of the pick-to-light system as efficient storage equipment. Noted that in Figure 7, a few sources are able to give a large value of throughput rate, especially at Source_OPT1_1 where the creation rate of model 3 achieved 60 units per working hour compared with model 1 and 2, where the correlation of the value is not high. Same as throughput rate at Source_RC_Bin_1, even though it has the mode value, the correlation between model 2 is not strong. But, model 2 and 3 throughput rate give a very strong correlation than model 1. That is most likely because of the changes in material handling and layout of the system.

Comparison of Throughput Rate at Warehouse

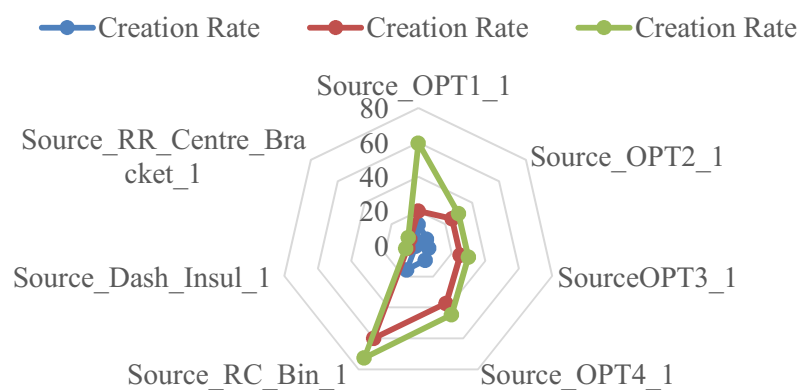


Figure 8. The chart area for comparison of throughput rate at warehouse

Figure 9 shows a linear graph for comparison of idle time in assembly line supply buffer. The data of model 1 shows that starting at Assem_Line_Buffer_1, the supply time reduce sharply into Assem_Line_Buffer_2. Based on layout configuration, the distance between both buffers is not too far from each other. Therefore, transportation is able to transfer parts faster, thus avoid from wasting time. But, as part transferring goes on, the idle time increasing along the other buffers. Differ with model 2 and 3, where the idle time reduces dramatically. The buffer that has highest idle time in model 1 is at Assem_Line_Buffer_10 (the last drop off stations), which is 2.877 hr. It is believe that the value is high due to the effect of waiting for transport to transfer parts first at 9 buffers before arrived at the last buffer. Noted that the idle time of model 2 and 3 does not show a strong correlation due to the application of transport equipment is same. The idle time still shows improvement where it reduces in average from 0.347 hour in model 2 into 0.292 hour in model 3. These averages shows, a 16% of idle time decrement in model 3. The buffer's idle time for model 2 and 3 shows a steady line and no major difference of idle time between every buffer. It's proved that AGVs are able to cope with the supply demand and distribute parts faster.

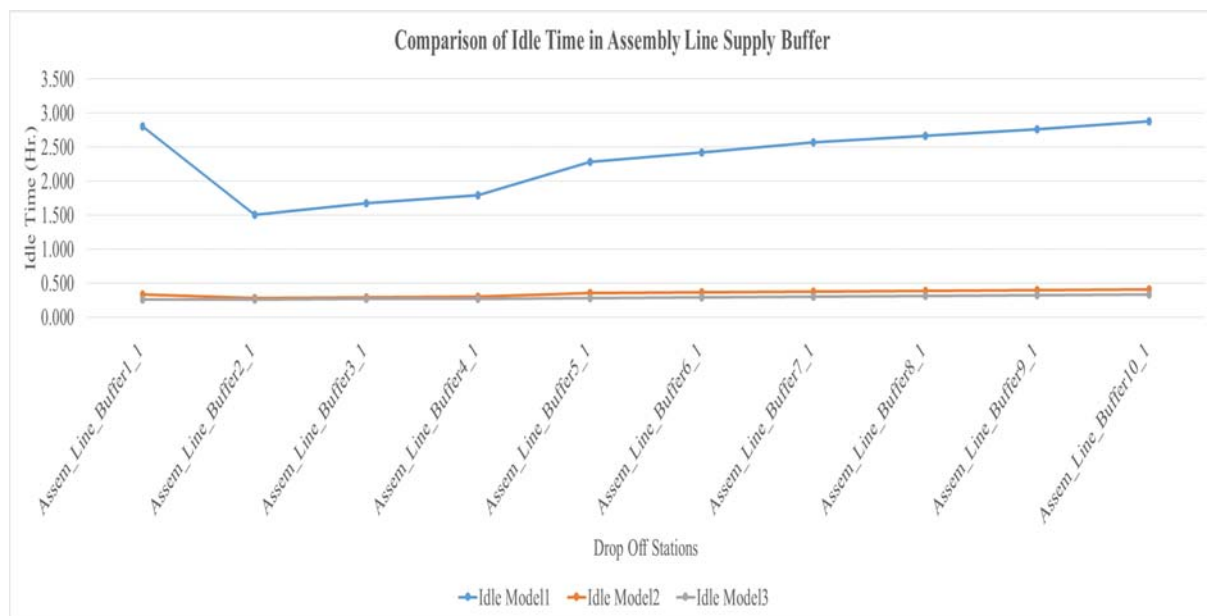


Figure 9. The line graph for comparison of idle time in assembly line supply buffer

A linear graph also is used to illustrate the comparison of parts entries in assembly line supply buffer as shown in Figure 10. The comparison is made to show how many parts are supplied at assembly line by transportation during working hour. The number of part entries in assembly line supply buffer maintain steadily in model 1. But, the average part supplies are only 32 units. Meanwhile, the value increases tremendously, in model 2 as much as 178 units. The increment percentage achieved more than 4 fold from the current system. Not to mention, the value of part entries at model 3 increase rapidly as much as 290 units in average. For an example, the upper extreme of part entries for every model holds by Assem_Line_Buffer6. This is due to higher demands from the assembly line at station 6. It also shows the part entries on model 2 and 3 give up and down values compared to model 1. The parts in every station have a different quantity to be transferred. Thus, the part entries are different from every station based on the demands along the period.

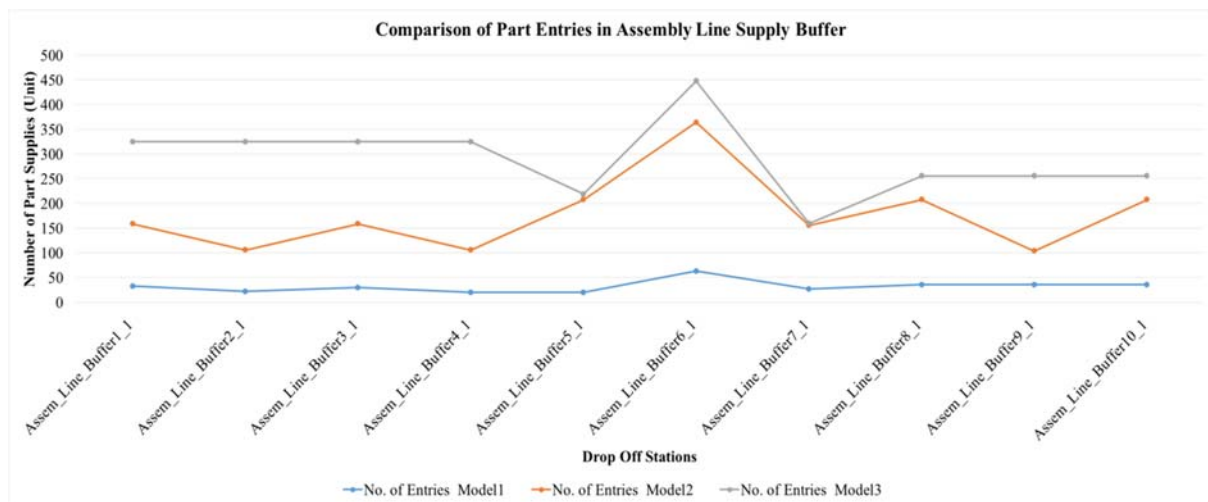


Figure 10. The line graph for comparison of part entries in assembly line supply buffer

In addition, the average waiting time of transportation reduced where the application of AGV allows transferring parts efficiently and saving time. As describe in Figure 11, the pie chart shows a comparison of average waiting time at warehouse pick up point. Model 2 and 3 shows a decrement value in warehouse buffer waiting time compared to model 1. Especially for model 3, the average waiting time improved better than model 2 average waiting times. In general, the current waiting time of parts in warehouse buffer from 0.716 hour (model 1) reduced to only 0.107 hour (model 3).

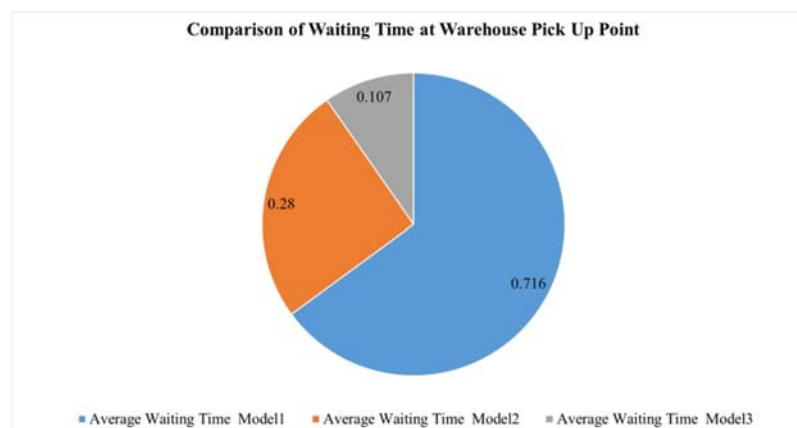


Figure 11. Pie chart for comparison of waiting time at warehouse pick up point

5. Conclusions

The purpose of this study is to propose a new design of integration between material handling and layout by investigating the influences of layout and material handling system in order to improve the automotive assembly line performance. For manufacturing strategy and constraint, this research work field is focused on the improvement of integration between material handling system and facility layout in current case study situation.

Thus, overall result shows, the application of AGV and the pick-to-light system gave a large significant effect in the automotive assembly line. Not to mention, the changes of layout show a bonus improvement to the performance. Hence, it can be concluded that the result obtained shows the influences of material handling system and facility layout in increasing the performance of the automotive assembly factory as well as other manufacturing fields.

A lot of aspects in this research study could not be covered at the same time, such as flexibility and industrial engineering scope. So, the constraint for this research work will be likely the manufacturing

towards flexibilities and leans. Flexible Manufacturing is defined as to push the process ability to quickly adapt to changes in the volume of goods produced. The objective is to remain competitiveness ability to customize their products to offer an advantage. But the constraint for this research work is that it will give high complexity for automated material handling system and in-depth study in the simulation using Delmia Quest software.

Meanwhile, as for lean manufacturing which also called Just In Time (JIT) manufacturing, it aims to make the manufacturing process as efficient as possible by eliminating waste. Such aspect will make the company employ workers with multiple skills, sets and develop an efficient handling system that produces a low percentage of waiting/delay material. However, all those constraints are under this research consideration for future work.

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