Investigating the Influences of Automated Guided Vehicles (AGVs) as Material Transportation for Automotive Assembly Process

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ABSTRACT

Optimizing material handling system adds to the performance level of the manufacturing process and at the same time avoid waste of time and cost. A case study at one of automotive manufacturing industry, focusing on observing the material flow between warehouse and assembly shop are done and the result showed the work is manually done. It's caused a longer time in handling the material and risk in damaging parts. Thus, a work presented in this paper is based on real industry situation, with the purpose of investigating the influences of AGV's application in the automotive assembly process. AGV (material transportation) and Pick-To-Light system (part supply system) are used as variable to improve the current case study performance. But in this paper, the result of comparison between transportation is discussed, focusing on the influences of AGV only. A method of discrete-event simulation using Delmia/Quest software was introduced. 2 models for each type of transportation is made in Quest with a very similar assembly process from the real situation in automotive industry and the result is compared to see the influenced of the AGV to the system performance. Based on the comparison, the part supply in the assembly process increase by 70% from its current state. Meanwhile, transportation idle time reduce by 26% and part waiting time at warehouse reduce at most 85%. Thus, transportation utilized more into 30% by applying AGV as material transportation. From the improvement made shows the influence of AGV in case study company as well as manufacturing industry.

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Introduction

Any movement of materials and parts through various stages are defined as material handling (MH). It does not add to the value of the product instead it only adds to the cost of the product because of the form utility provided by MH [1]. But, with MH providing time and place utility it can add a real value to the product [2, 3]. Due to the expensive direct labor, automated material handling system (AMHS) become trending worldwide [4].

This paper focuses on the effect of AGV as the automated transportation in handling material through the warehouse to the assembly line. A design on the transport system that is comparable with case study material handling system in the automotive industry will be done through simulation and the result will be analyzed based on the process performance.

Simulation is primarily intended to be useful technique as its integration of Computer-Aided Design and Computer-Aided Manufacturing is the main approach in the decision-making process and improving the quality of products and optimizing the time of production [5, 6]. Delmia/Quest V5 is the selected software to use in this project. It intended to prepare, setup, and perform the simulation for this research [7]. Without the possibility of destroying the elements in a factory or disturbing the system, users enable to experience the process of the target equipment by using simulation method. Knowledge can be enhanced and design cycle can be shortened by using this method [8]. Thus, as other simulation software, the Quest software is a powerful tool in assessing, modeling and analyzing changes that should be made in a complex manufacturing system [8, 9].

Preliminary Study

This paper is intended to show the effect of AGV application in handling material for the assembly process. Before replacing AGV with the current transportation, a remake of same material handling system in real industry case study is done using Delmia Quest software.

Preliminary data gathering from factory illustrates at Figure 1, it starts with observation into 2 places which are factory layout and material handling system. Observing and monitoring at the existing documentations and the part product inside factory are the main method used to gather all the data. A complete data covering production line and warehouse are gained for the possibility of integration system. Thus, a pilot study is done by changing the distance of transportation travel and the scheduling rule in the system. The result shows an increase in production by changing a layout and scheduling rule in the system [10]. From that, it motivates to research the effect of automated material handling in the system. The case study is based on an adaptation of automotive assembly line located in Selangor. Before improvement is made, all data collected by visiting the factory to judge the current production condition.

Methodology

The physical configuration provides the pneumatic artificial muscle with some desirable characteristics such as a variable stiffness or compliance, inherent damping, structural flexibility, as well as high power to weight ratio [1 – 4]. However, it exhibits a nonlinear relationship between the contracting force, internal pressure and its contraction length. In addition, the structural materials of the pneumatic artificial muscle inherently lead to hysteresis during cyclic contraction and extension [4]. This nonlinearity behaviour is addressed as a difficult error source to be handled especially during a precise positioning control. The hysteresis loops can be visibly seen by using an isometric test (i.e., force and length hysteresis) or an isotonic test (i.e., pressure and length hysteresis).

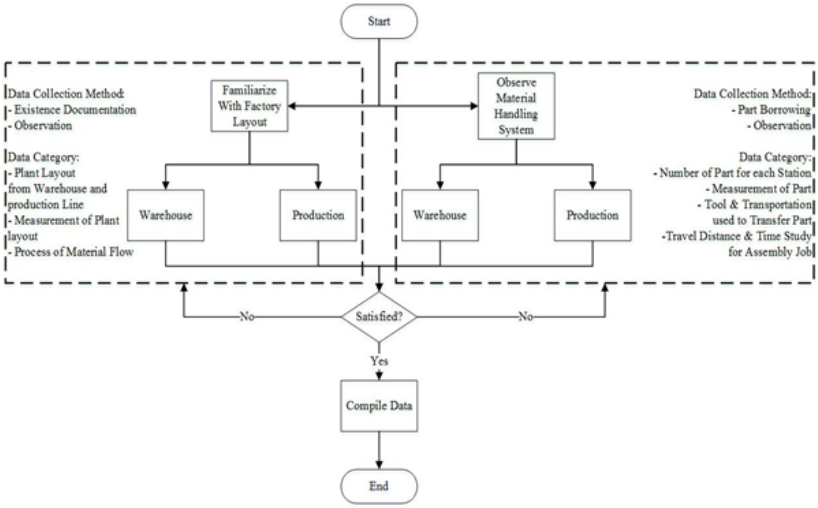

Figure 1: Preliminary data gathering for phase 1 process flow [10].

All the data and information gathered during the visit are then used for the Delmia Quest simulation. Some actual data that are needed from the factory will be the floor layout, number and name of the parts, the number of stations, the flow of material, the travel distance from warehouse to the assembly line and lastly, is the speed for both transport system. The main factors considered in the experiment is the type of transportation which consist of their speed and quantity. Table 1 illustrates the variations of those factors.

Table 1: Variations of factors

Layout	**MHS Configuration**		
	Transportation	**Number (Unit)**	**Speed (m/min)**
Loop layout	Tugger train	4	91.44
	AGV	4	45.72

The number of transportation from table 1 is calculated using a mathematical equation to describe the configuration of the vehicle of the vehicle-based material transport system. The equation used in this research work is starting with Equation (1), a total cycle time of delivery per vehicle, T_C goes by,

$$T_C = T_L + \frac{L_d}{v_c} + T_u + \frac{L_e}{v_e} \tag{1}$$

where T_L is the time to load at load station. L_d is the vehicle travel distance. v_c is the vehicle velocity. The time to unload at unload station, T_u also added including the division between travel distance of empty vehicle, L_e and velocity empty vehicle, v_e.

Equation (2) is a proportion of total shift time transportation breakdown. The delivery cycle time, T_C is calculated as ideal value because the possibilities of time losses because of reliability problems, traffic congestion and etc. are ignored. But in order to calculate the ideal quantity of transport the time losses need to be considered. Thus, time losses due to traffic congestion, availability and efficiency of manual driver (if available) will be calculated.

Availability, A defined as the proportion of total shift time that the vehicle is operational and not broken down or being repaired. Availability also defined using 2 reliability terms, mean time between failures (MTBF) and mean time to repair (MTTR). It calculated as,

$$A = \frac{MTBF - MTTR}{MTBF} \tag{2}$$

Traffic congestion is defined as traffic factor, T_f as a parameter to estimate the effect of losses on system performance. Traffic factor accounted such as waiting at intersections, blocking of vehicles and waiting in a queue at load or unload stations. Starting from little or no blocking occurred it will be 1.0 and it will decrease as blocking or traffic congestion increase. Typical values of traffic factor for a AGVs range between 0.85 and 1.0. From all the time losses factors, available time can be express as is,

$$AT = 60AT_fE \tag{3}$$

where AT is available time and E stand for worker efficiency. The rate of deliveries per vehicle, R_{dv} is express as,

$$R_{dv} = \frac{AT}{T_c} \tag{4}$$

where the rate is a division between Equation (3) and (1). Meanwhile, in Equation (5) illustrates the total amount of work that will proficient by the material transport system in 1 hour.

$$WL = R_fT_c \tag{5}$$

where WL stand for workload equal from flow rate of deliveries per hour, R_f multiplied with cycle time, T_c. Now the number of vehicles can be expressed and summarize as,

$$n_c = \frac{WL}{AT} = \frac{R_f}{R_{dv}} \tag{6}$$

where, n_c is the number of vehicles required.

A few assumptions will be made such as the velocity is constant through its operation and any changes of speed such as acceleration or deceleration will be ignored. The difference of speed that happens the vehicle traveling loaded or empty also will be ignored. All calculation above state the quantity amount of transport equipment based on travel distance to every drop-off stations and type of storage equipment for both layouts. In Table 2 illustrates the overall summary of the calculation which consists of transportation configuration such as, loading time, unloading time, velocity, flow rate and etc. this configuration also being used in Delmia Quest programming.

Table 2: Summary of transportation configuration

MHS Configuration	AGV	Tugger Train (Manual drive)
Loading Time, T_L	Picking List: 1.99 min Pick – To – Light: 1.1 min	
Velocity (carrying/empty condition)	91.44 m/min	45.72 m/min
Unload Time, T_u	0.55 min	
Distance vehicle travel empty, L_e	0	
Flow rate, R_f	31 del/hr	
Overall distance vehicle, L_d	363.4 m	
Availability, A	0.95	0.90
Traffic Factor, T_f	0.95	
Operator Efficiency, E	1.0	0.95

Simulation of Manufacturing System in Quest

Before replacing AGV with the current transportation, a remake of same material handling system in real industry case study is done using Delmia Quest software. The layout shown in Figure 2 is the current layout in real case study industry. The figure illustrates the transportation track from warehouse to assembly line which is called trim line and chassis line. This research work only focuses on chassis line which consists of 10 stations with different process and part supplies. In addition, it also shows the distance traveled from warehouse to assembly line. In assembly line, each process has their own stations and each station is not fixed with only one process. It involves assemblies of 3 to 4 types of different parts for each station. Basically, the distance traveled is according 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.

Meanwhile, Figure 3 is the layout used in Delmia Quest software. They are the floor layout of automotive assembly process used in this research experiment. The Quest model analyzed was based on a sample manufacturing facility from the automotive industry. This manufacturing facility has 10 drops off/supply station and 1 pickup station at the warehouse. Each station is modeled as a buffer in Quest and accompany by labors for assembly job. There are 31 different parts is supply every day and transferred by a train drive by workers.

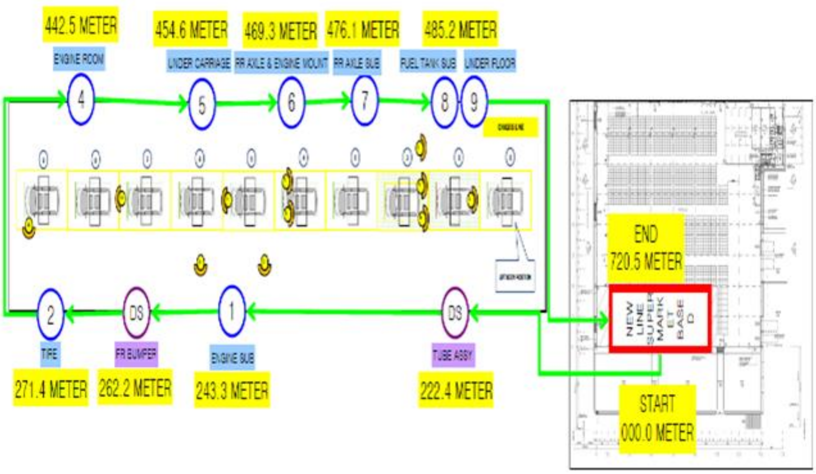

Figure 2: Real case study layout

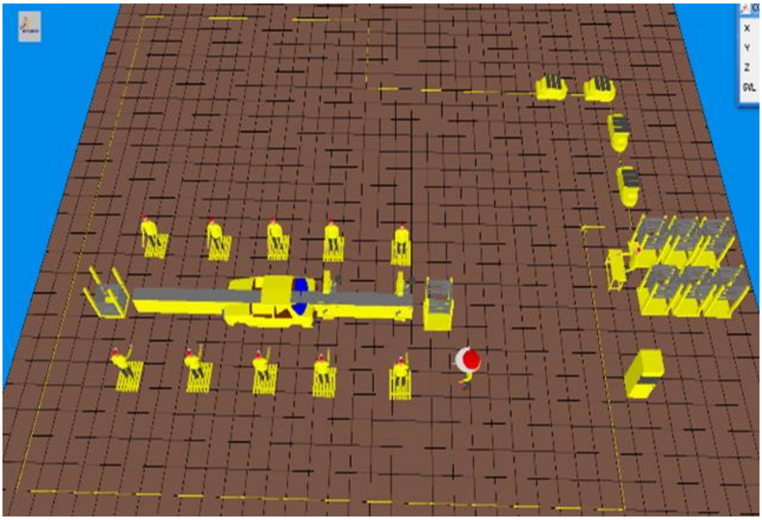

Figure 3: Delmia Quest layout

As indicated at previous studies, Delmia Quest used model validation which in logic that a valid model will be able to produce a reasonable prediction of the system's performance [9]. The result from the Quest simulation divided into 3 elements. Such as the production rate, bottleneck and transport utilization as shown in Table 3. The detailed formula for each elements statistic is taken from Delmia Quest user manual [11].

The simulation corresponds to a 9 hours workday including of 8 hours of actual work and 1 hour of breaks. The amount of time the laborer takes to handle material is approximately less than 60sec. All the input and output of element class using push system and the First In First Out (FIFO) for queuing system. Noted that in the experiment, the layout remains constant.

The material flow was taken from case study through observation of process flow from warehouse to the assembly line. All parts involved in this research work is only used to assemble one type of car model as shown in Figure 4 where the assembly process is done by the operator. Figure 5 show the flow diagram of material and transportation flows in the assembly system. This process flow is important in order to help in constructing a simulation control language in Delmia Quest software. The left column of the flowchart is from warehouse section, consist of 7 racks which function as pick up station in the simulation. Meanwhile, the right column is at assembly line drop-off stations. Vehicles will pick up parts according to sequence linearly and transfer the parts based on the direction of layout in Figure 2. Same as drop-off stations, vehicles will transfer parts in sequence based on 1st stations it arrived.

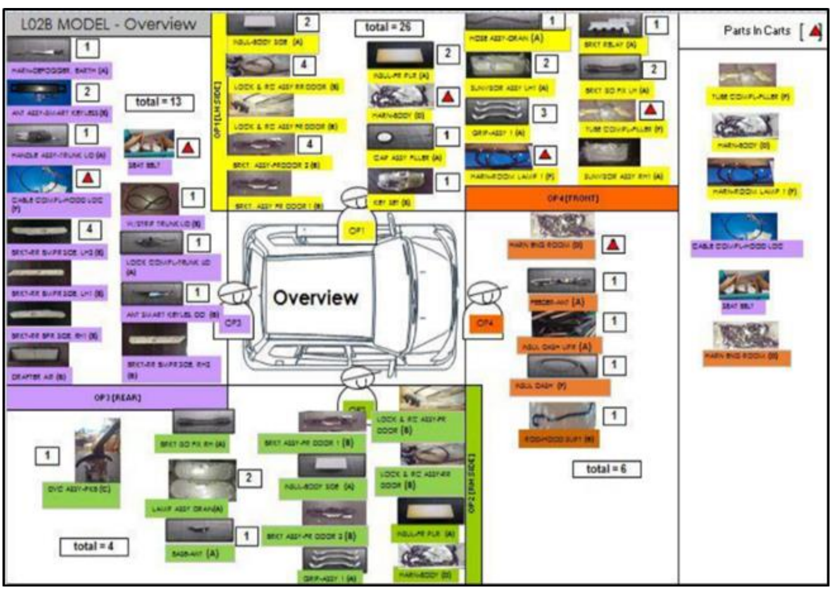

Figure 4: Part positioning for the car model.

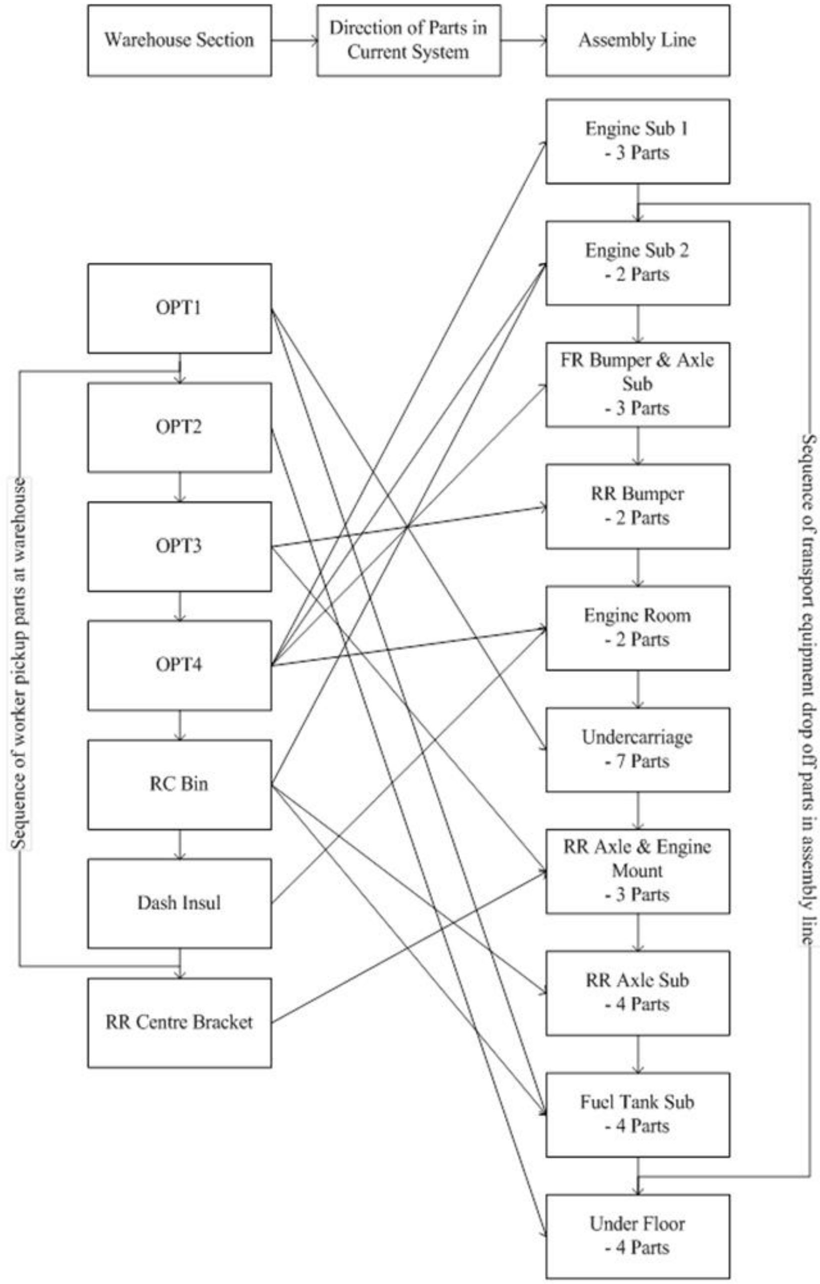

Figure 5: Flow diagram of parts allocation and transportation flows.

Table 3: Result presentation

Element class statistic	Formulas
Sources statistic	
a. Creation rate	Number of parts / Simulation runtime
Buffer statistic (Bottleneck)	
a. Idle time	Σ total time an element was no executing any processes
b. Average waiting time	(Max. waiting time + Min. waiting time) / 2
Transport statistic	
a. Num. of transport claimed with no wait	Numbers of transport that did not have to wait in every station.

Effect of AGV in Manufacturing System

The improvement was done by replacing the current manual transportation of handling materials to automated material handling system which is AGV. Model 1 (TRAIN) is simulation model contain assembly system with current transportation which is tugger train to transport material from warehouse to assembly line. Meanwhile, model 1 (AGV) contain the same assembly system but with AGV as material transportation. The output of the proposed transport system are determined and compared with the current transportation system in order to validate the new model with AGV.

Before that, the result of simulation for model 1 is compared with the current case study situation. It is in order to prove the system of model 1 is valid when the system able to produce output as well as the case study production output. Table 4 shows the comparison of production output between real industry situation and simulation. The output of cycles in 8 hours for both before and after the simulation is same. Thus, prove that model 1 able to simulate as same as the real industry situation.

Table 4: Production output of real industry situation (before simulation) and model 1 (after simulation)

<table>
<tr><th>Model</th><th>Real industry situation</th><th>Model 1</th></tr>
<tr><td>Speed of train</td><td colspan="2">91.44 m/min</td></tr>
<tr><td>Cycle per 8 hours</td><td>14 cycles</td><td>14 cycles</td></tr>
<tr><td>1 cycle takes</td><td colspan="2"><36 minutes</td></tr>
<tr><td>Distance</td><td colspan="2">486.2 m</td></tr>
</table>

The improvement can be seen at the number of assembling part supply left after simulation working hour which is the average part supply by train is only 5.6 parts rather than AGV supply as much as 9.7 parts. The increment likely due to the ability of AGV to supply parts in assembly line. Thus the value increases approximately 70% from its current state. Meanwhile, the total part supplied during and after the simulation working hour is increase as much as 35% from its current state. Due to increase in part supply demand, the part creation rate at warehouse also increase as shown in graph in Figure 6, the comparison of part creation rate at warehouse shows the highest unit created is at RC Bin source station as much as 20.3 unit/hour by using AGV as material transportation instead of using tugger train that resulted in only 15 unit/hour.

Figure 7 represents a graph of comparison bottleneck in assembly line supply buffer where the part is drop off by AGV. It's shown that application of AGV reduce the idle time by 26%, where the average difference of AGV idle time is 0.6 hours from 2.3 hours idle time of the train. Thus reduce the bottleneck at the buffer stations. In addition, Figure 8 also shows the bottleneck reduced where the average waiting time of the AGV to pick up part is reduced at 0.594 hours from 0.716 hours of a train waiting time. That shows the bottleneck also reduced as much as 83%. Lastly, the AGV itself is utilized 30% more than the current transportation, where the average number of AGVs claimed with no waiting time is 14.45 AGVs higher than trains which are 11.09 trains claimed with no waiting time.

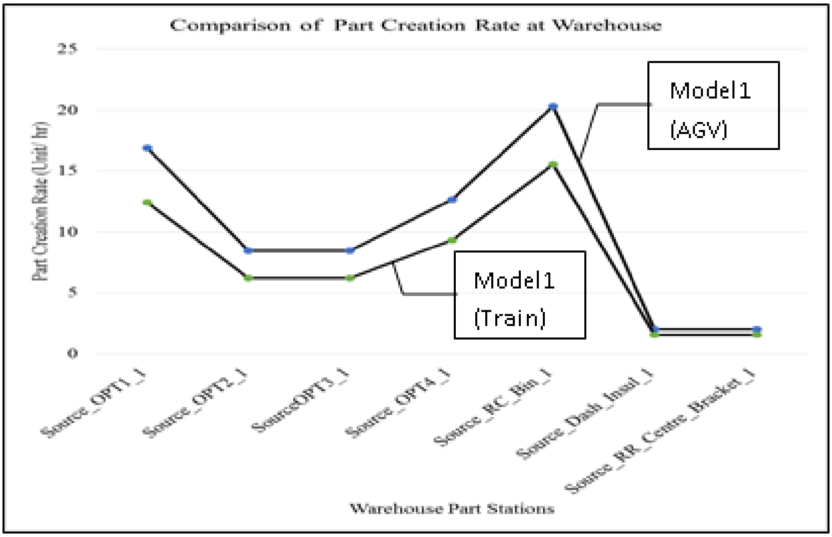

Figure 6: Graph of part creation rate at warehouse

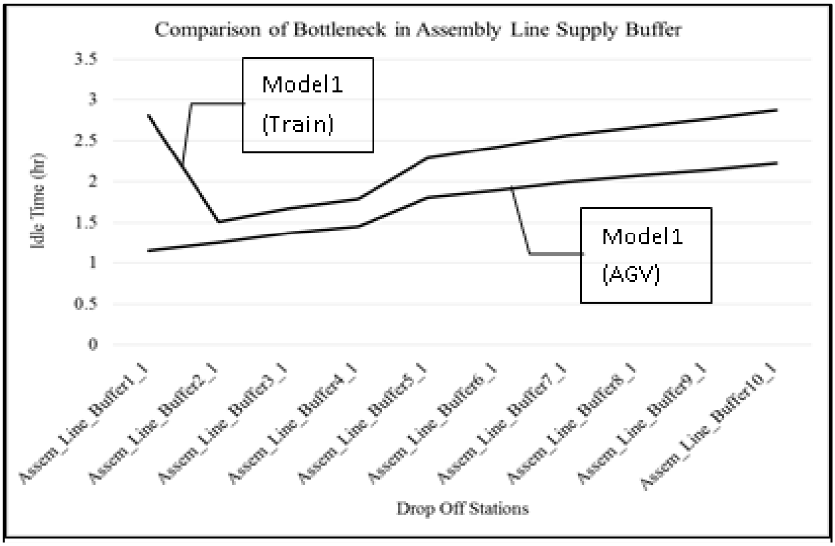

Figure 7: Graph of transportation idle time

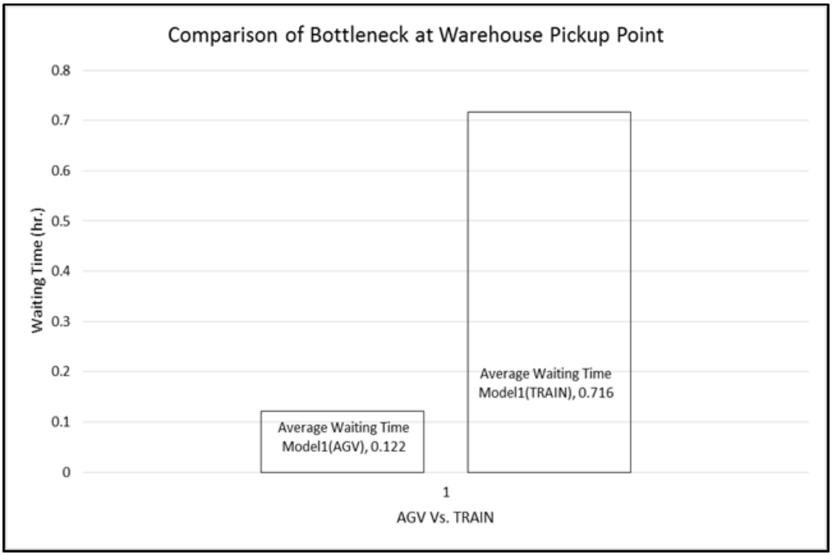

Figure 8: Graph of transportation average waiting time

Conclusions

Ability to illustrate and simulate the functioning of the manufacturing cell has to make simulation become as one of the trending methodologies in manufacturing engineering field and it's also cover the dynamic analysis, before execution of the production system, thus reduce at the minimum cost and the stocks.

In this paper, the simulation of the manufacturing line is presented using Delmia Quest software in order to simulate and to optimize the material handling system. Thus, give an idea to discuss the influences of AGV application in handling material at automotive assembly process. With the result, it consequently reduced the idle time of the production buffer and warehouse buffer tremendously. The result shows the AGV's influences in a manufacturing system, where the benefit in using automated material handling system is large. The improvement in part supply in the assembly process increase as high as 70% from its current state. Meanwhile, transportation idle time reduce by 26% and part waiting time at warehouse reduce at most 85%. Thus, transportation utilized more into 30% by applying AGV as material transportation. From the improvement made shows the importance of AGV in case study company as well as manufacturing industry.

By using simulation in Quest not only one variable at the time could be tested but also how combined changes affected the system. The ability to test and measure the result will lead the ability to forecast the effects of the changes. With the right model, it will just take a few moments to get a similar data that would take days even years to measure out of the real production cell.

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