Methodology on Investigating the Influences of Automated Material Handling System in

Automotive Assembly Process

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A case study was selected as a method to collect data in actual industry situation. The study aimed to assess the influences of automated material handling system in automotive industry by proposing a new design of integration system through simulation, and analyze the significant effect and influence of the system. The method approach tool will be CAD Software (Delmia & Quest). The process of preliminary data gathering in phase 1 will collect all data related from actual industry situation. It is expected to produce a guideline and limitation in designing a new integration system later. In phase 2, an idea or concept of design will be done by using 10 principles of design consideration for manufacturing. A full factorial design will be used as design of experiment in order to analyze the performance measured of the integration system with the current system in case study. From the result of the experiment, an ANOVA analysis will be done to study the performance measured. Thus, it is expected that influences can be seen from the improvement made in the system.

1. Introduction
In ages before, Japan and Western Europe went trending to the autonomous material handling because of the expensive direct labour. Definition of MH cover short-distance movement within restrains building [1]. Meanwhile, Compton's Interactive Encyclopaedia defines MH as "The movement of raw materials, semi-finished goods, and finished articles through various stages of production and warehousing". MH is often said that is 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 [2].

But, with MH providing time and place utility it can add a real value to a product [3] [4]. From fully manual operations, MH has evolved immensely where workers were hired to lift, stack and count [5]. Material handling system has becoming a requirement in manufacturing system as "Improving your material handling system fuels a stunning return on investment. It makes more sense than almost anything else you can do" [6].

The ideology of this research is to assess the influences of automated material handling system in manufacturing industry. The primary goal of applying material handling system is to ensure that the material is in the right quantity and delivered safely at the right time and at minimum cost to desired destination.

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The most importance factor of material handling is the safety of the worker [7]. It is supported in material handling equipment article [6] that the efficiency of material handling equipment adds to performance level of the manufacturing process. Thus, it is crucial to solve issues happen in material handling system to avoid waste of time and cost while at the same time reduce risk of material damaged and increase worker safety and health. In addition, implementation of recent technology in material handling system is also important in order to have a worth changing of system in production process.

By studying a proper method and process to design a material handling system and observes the influences in term of effectiveness and efficiency of the system, it can contribute to improve the future material handling system in various industry especially manufacturing industry. Current demand in technology and system of automated material handling is increasing, and the study trending in the optimization of effective and efficient material handling system is arising, in order to have income in product. Current issues such as insufficient material handling [8], old technology implementation [9] separation of production system and material handling system can cause various problems in term of cost and time consuming [10]. But, the obvious gap that can be seen for the problem is actually on the tools or the platform that integrates between material supply in production line and inventory system in warehouse.

The issues can contribute to reduction of production efficiency where time required for an operator to do work has been wasted. Based on case study observation done in automotive factory, the production background is begin from logistic warehouse to body shop, paint shop and lastly is assembly shop where the painted body is assemble in three main stations which are trim line, chassis line and final assembly line. The process during assembly is done by semi-auto processes that involve manual and auto system. Studies are focused at the assembly shop where it is noticed that the process flow of material from warehouse to assembly line is done fully manually. Thus it took time in trafficking the material and high risk of damage (either human or material) when transfer the material. Thus, a possible solution is by modelling an integration between production system and material supply system using a proper design of material handling system.

The main purpose of this study is to assess the influences of automated material handling system in automotive industry by proposing a new integration system of material handling system. A design on the integration system that is comparable with current system of material handling system in the automotive industry will be done through simulation and analysis of the influences of the new system with the conventional system will be done in order to achieve the main objective.

2. Literature Review

The study will focus in material transport system and review for conveyor, automated guided vehicle (AGV), pick and place robot arm, and autonomous mobile robot (AMR). There is various methods of material handling system design and the most general method is: defining the objectives; establishing the scope; analysing the requirements of moving; determining storage and control of materials; generate and evaluating alternatives; selecting the preferred material handling system; and implementing system [11].

The same method was applied in developing a simulation programming using knowledge-ware application [12]. The author aims to have a proper material handling system that is suited with the production line. The method he used was divided into 3 phases starting from concept design until simulation development. He suggests knowledge-ware application which can help to improve material handling design. The same 3 phase method was also applied by another authors, but with addition of a last phase which is the result of simulation [13]. The principles usually were collected before starting the design and become the design scope limitation. A limitation and available parameter was used as a guidelines to design the automatic material handling system for engraving machine in order to develop effective and efficient forms of production. The develop system is able to complete the engraving operation and increase the productivity 3 times then the manual material handling system [14].

In addition, there are ten principles that provide important guide for designing material handling system such as, planning; standardization; work; ergonomics; unit load; space utilization; system;

automation; environment; and life cycle [15]. Those principles were reviewed in selecting appropriate handling equipment in engineering industries [16]. Knowing the ten principles bring in question on how to choose a proper material handling equipment and how to overcome operational problem. To answer those questions is by analysing the effectiveness of the material handling system.

Proposed methods in analysing usually analytical which are mathematical and regression modelling [17] [18] [19]. From the studies, the authors present a possible solution approaches for choosing the type of material handling equipment and design constraints forced by a large system.

Simulation in this study focuses in design and analyses material handling system. Software has been used from other researcher to simulate their material handling system. In 90s', a mix of tool has been used for model development such as: Autosched, Mansim, Siman and Modsim and AutoMod [20]. The authors also stated that the simulation played a key role in material handling system and become standard step in design cycle. More recent software is ARENA, ExtendSim v8, Delmia v5 and Quest v5. All the listed software are using discrete-event simulation method where the model operation system as discrete sequence of events in time.

Review on the material supply and material feeding classified the usual supply type used in industry and lists the tracking system in material supply management. From the review of such topics, a few tools and methods can be applied to solve supply chain problems such as Radio-frequency identification (RFID), Lean system and Vendor-managed inventory (VMI). A problem in material supply is also listed and all the proposed solutions are mostly focus on the tools and system itself. The general method in designing material handling system eventually is a better method to be used, but need to be in more detail and specific where the process of equipment and material selection is properly show. The first stage usually will undergo trial and error process which is known as heuristic technique in order to know the parameter need to be taken. But the structure of the technique can go deeper by using analytical or regression method in order to obtain a hypothesis before going to simulation analysis.

For simulation analysis, future work for this study will use Delmia v5 as simulation tool in addition to Quest v5 software to undergo a virtual 3D simulation with ergonomic human movement in order to obtain the analysis result. By using the proper selection of method and tools, it is expected to have an efficient and effective automated material handling system.

3. Overall Process Flow

The process flow shown in Figure 1 consists of 5 phases starting from phase 1 which involve literature review and preliminary data gathering. Phase 1 is meant to understanding research problem and assess data from case study in real automotive manufacturing environment. Next is phase 2 which aim to design and propose a new material handling system. The design proposal has its own flowchart that will be explain later. In this phase, a decision block is put in order to have a satisfaction design so that the process can proceed to the next phase. After that, phase 3 is where the research will conduct experiments in order to analyse the performance measure of both current and new system. Later on, phase 3.5 will comprise all the data and using statistical analysis, the data will be analysed in phase 4. Lastly, a documentation which will write a complete report including the conclusion and recommendation as a close up to this research project.

3.1 Phase 1: Understanding Research Problem and Case Study
In phase 1, its aim is to understand the research problem and review other research works that has been done in the research area. The literature review covered is one of the process to gain more knowledge for this project, the technology and current trending, the method and simulation software that has been used to solve research problem. Meanwhile, for preliminary data gathering is meant to collect data from case study, taken from actual industry situation as preliminary guideline and limitation to design a new material handling design. The data gathering process is shown in Figure 2. The flow starting with 2 systems division which are factory layout and material handling system. Main method to gain preliminary data on both systems is using observation and monitoring at the existing documentations and part product inside factory. Both systems will cover on production line and warehouse to gain a

complete data for possibility of integration system. Data category is shown in flowchart. Data compiling will be done after all data collection has been satisfied.
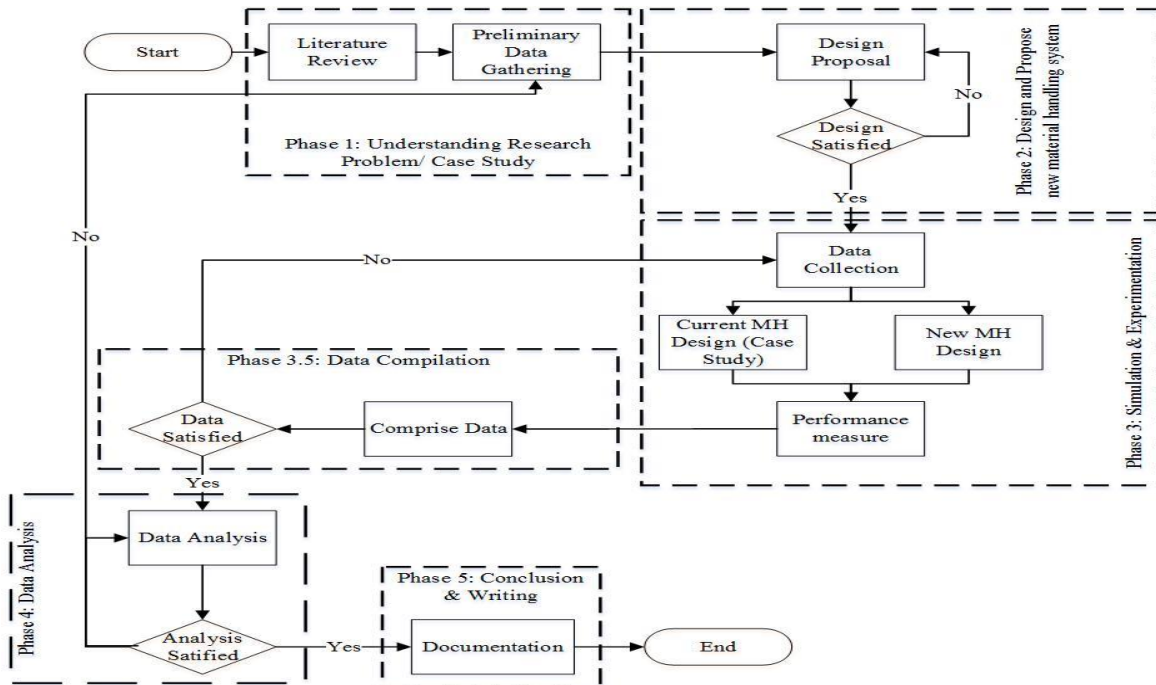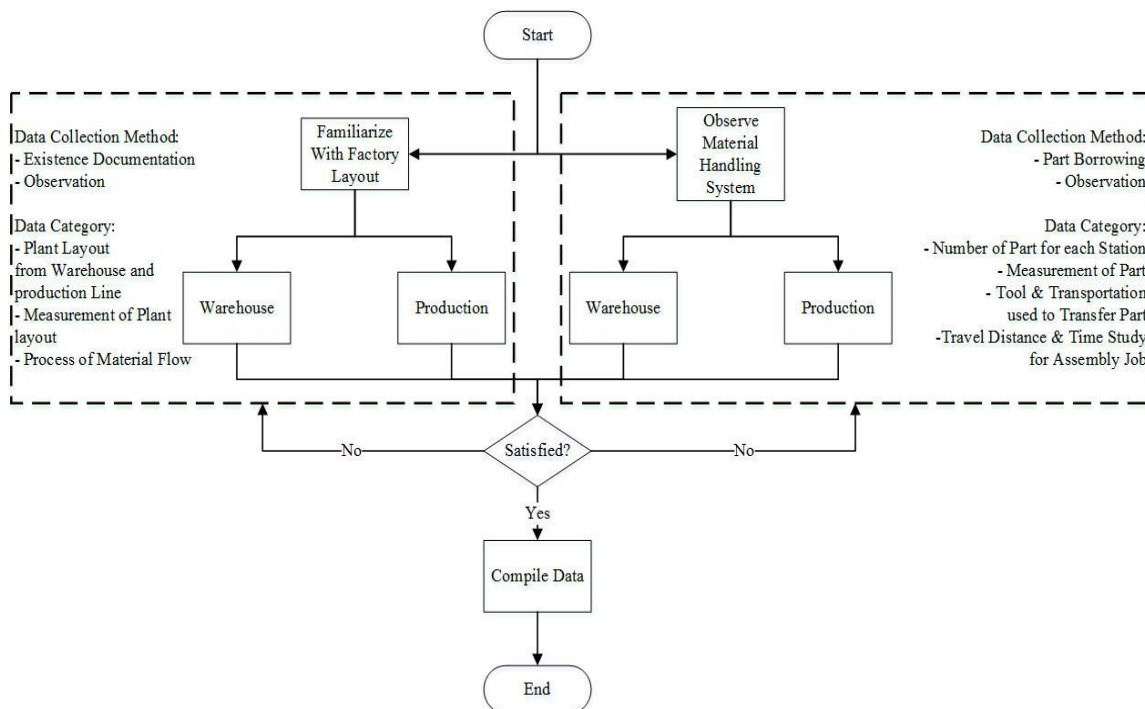

Figure 1: Overall project flow chart.

Figure 2: Preliminary data gathering for phase 1 process flow.

3.2 Phase 2: Design and Propose New Material Handling System
In phase 2, a new material handling system that will integrate both production and warehouse layout will be designed based on automated technology as shown in Figure 3. It purpose is to achieve first objective of this research work which is to design an integration system of material handling system through simulation. Starting with planning where current problem will be clarified and all design considerations will be taken into note.

As for design consideration, this research work is considering the 10 principles of material handling system. But, only 7 principles will be used and will be detailed more in consideration of cost and environment as both factors are important in design for manufacturing industry and society health.

For a cost consideration, in order to gain a proper calculation for Bill of Material (BOM), a procedure of Design for Manufacturing (DFM) method will be used. Meanwhile, Design for Environment will be used as a process in consideration for environment. Next step is basic idea and design concept will be created with the aided of CAD software by using Delmia and Quest software. It also aim to achieve the second objective which is to simulate the design concept by using the same software. Until design concept is satisfied, the process will be repeated.

After system is reviewed, a selection will be done to choose the best design system to be compared with the current system of the real industry situation. All the designs will undergo evaluation test by comparing their failure and cycle time value. The result of comparison can be used to study the influence of automated material handling system with the conventional material handling system. Later on, in order to validate the design, all the components' performance will be tested whether it is working properly or not and as well as whether it satisfies the system requirement or not.
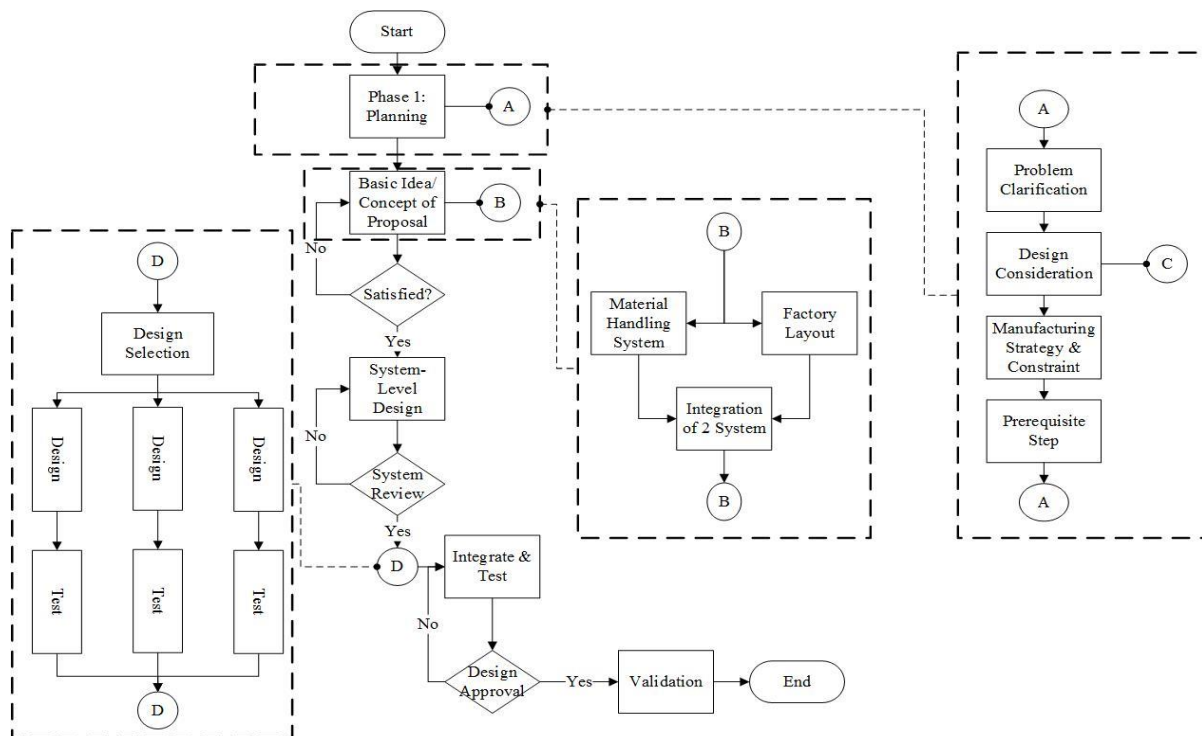

Figure 3: Design process flow for new material handling system

4. Design of Experiment
In the process flow of phase 3 experiments will be conducted as the data collected can be used to analyse the performance measure of the integration system with the conventional system in case study. A full factorial designs is proposed to be used as the design of experiment. First process required in full

factorial design is to identify all the variables of factors needed for the experiment. The experiment will be conducted by using 3 factors with 2 levels each, 2^3. The factors are shown in Table 1 including its levels.

The experiment is using full factorial design to be conducted and ANOVA test will be performed to analyse the performance indicators such as average cycle time, average Work In Progress (WIP) and percentage on time recorded. In addition, the current/ old system in the case study also will be simulated to gain data and compare with the proposed design result to study the significant effect of changing system with the actual industry situation.

Table 1: List of factors and levels that will be used as manipulated variable.

Factor	Level	
Transportation Type	Tugger Train (TT)	Automated Guided Vehicle (AGV)
Factory Layout	Old Layout (Case Study) (OL)	New Layout (as Proposed) (NL)
Supply Order System	Picking List (Maruka) (PL)	Pick-To-Light System (PTL)

5. Review on Methodology

Basically phase 4 is where the results will be obtained and recorded to analyse the responses. The data will be compiled and ANOVA Test is performed. It is expected to show the significant effect of improvement comparing to current system available in the case study. The analysis of the data is expected to identify which system is able to have highest utilization performance and high percentage on cycle time recorded.

Before that, in preliminary data gathering show a significant changes in production by changing a layout and scheduling rule in the system. From changing a simple loop layout into cellular layout as shown in Table 2 resulted in improvement where the distance of material travelling has shorten and as the throughput time to move material shorten the quantity of output was increase. From that, even a slight change of layout facility can give a significant influences in material handling. As shown in Figure 4, new layout can produce higher quantity of product in certain arrival time then old layout. Shows, a slight changes of factor can influences the system Thus, by investigating the influences is very importance in order to identify a better system in future.

Table 2: Changes of layout facility in actual process.

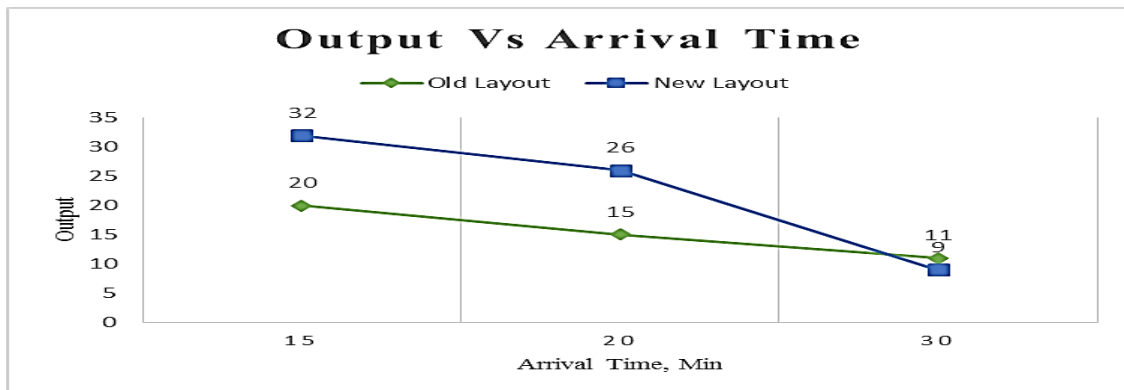| Old layout from supermarket to chassis line	The layout of new system
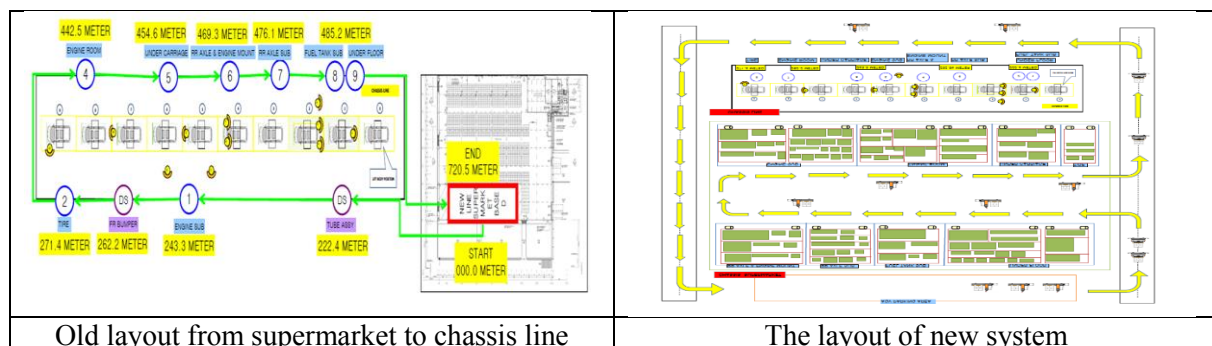
Figure 4: Output comparison between old layout and new layout

The method used was reviewed from few journal papers which focused on full factorial design as their method. The step mostly same where all the factor is used by investigating one factor as several levels of other factor yielding conclusions that are effective over a range of experimental conditions. But, the variable and output that was analysed were different.

Experiment method usually involves the Design on Experiment (DoE) as a methodology to investigate qualitatively or quantitatively variable in the study. Example application of full factorial design as the design of experiment to analyze dispatching rules for AMHS and processing tools in semiconductor fabs [21]. The experiment was design in order to prove the authors hypothesis that there are significant impact given by interaction or combination between vehicle and machine dispatching rules in fab performance. The experiment consist of 2 manipulated variables which are divided into five machine dispatching rules (machine DR) and seven vehicle-initiated dispatching rules (vehicle DR). Each variable will be combined to test the hypothesis. ANOVA test are performed at 95% confidence level and show the interaction between machine and vehicle.

Experiment method was also used to study the optimization by the design of experiment techniques [22]. The authors state the most common optimizations design of experiment used Response Surface Method (RSM). An example of RSM application is a test for optimizing the sealing strength of two identical polyethylene (PE) films [23]. The experiment was using central composite design with three continuous factors at five levels which the factors was found from screening test done before starting the RSM. The screening test was done using full factorial design in order to find the optimal factor that will affect the sealing strength. The factors that affect resultant seal strength were screened onto 3 factors which are percentage of PE, cooling temperature and sealing temperature.

The factors and level contain of 4 factors with 3 levels each. The factor (parameter) that was selected and level of the values are found from the previous research. Basically, using the Full Factorial Design as the design of this experiment is possible but the running process will be large and took a longer time. Thus, by using Taguchi allowed those values be selected using orthogonal array selected ($L_9 3^4$).Then, a data is collected by measuring the defect and mechanical properties that effected from the manipulated parameters. Meanwhile, after collecting data during experiment, the data was analyzed by using ANOVA to identify the utmost important parameter that influent defect and mechanical properties. From the research has been done, all the three independent variables were influence by the most significant factor which is injection time. In addition, based on ANOVA analysis, injection pressure on significant in defects then mechanical property.

In Figure 5, shows a comparison from few journal papers based on performance measure that has been investigated including the performance measure this paper going to analyzed. It shows the manufacturing metric that was used by other author and this paper. A few important manufacturing metrics from Manufacturing Enterprise Solutions Association (MESA) was selected as the selection factor and the metrics was grouped based on associated top-level area of improvement/goal for each which show at the Figure 5 as the performance measure. The information of the manufacturing metric

can be refer to [27]. The detail metrics that was used by each papers and this paper is presented in Table 3.
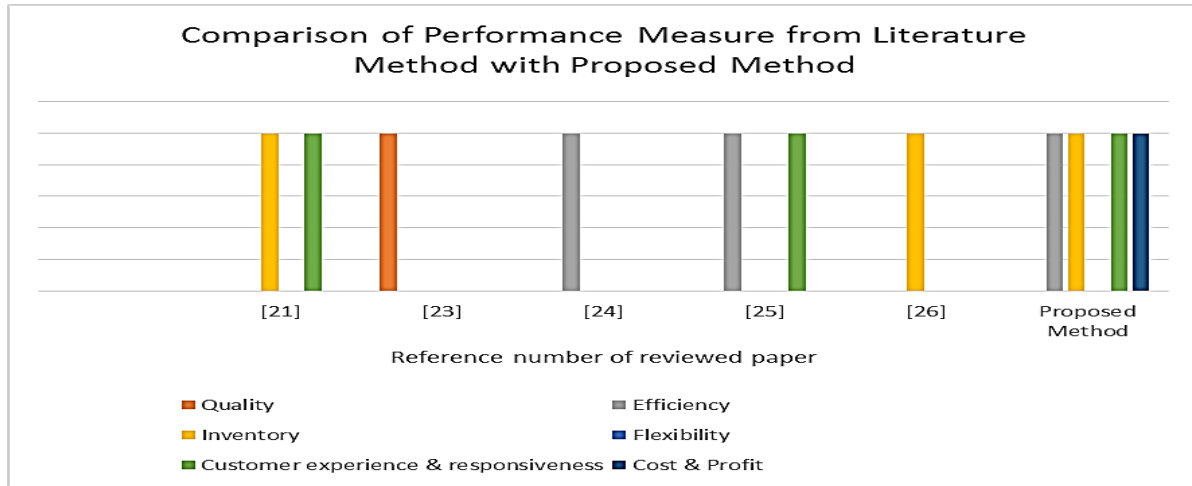

Figure 5: Comparison of performance measure from literature method with proposed method

Table 3: Detail metrics used by other authors as their performance measure

Performance Measure Metrics [27]	Method Reviewed on Performance Measure					
	[21]	[23]	[24]	[25]	[26]	Proposed Method
Quality		Material properties study				
Efficiency			Throughput time study, schedule attainment	Throughput time		Throughput time, Machine utilization
Inventory	Average Work in Process				Work in Process	Work in Process
Flexibility						
Customer experience & responsiveness	Average cycle time			Travel Time		Average cycle time
Cost & Profit						Design for Manufacturing

Based on above comparison, this paper analyze more performance measure than other authors. Due to the response variable resulted from manipulating factor such as transportation (the number of AGV/tugger train, speed of AGV/tugger train), factory layout (Distance of material travel from warehouse to production line, quantity of pit stop) and supply order system (quantity of unit based on part/bin, operation time/length) and software capability in producing measuring data. Furthermore, by analyzing more performance measure, interaction between factors that influences the system can be seen. Thus, propose the new system of automated material handling system that include all factor that influences the performance of automotive assembly process.

6. Conclusion

As a conclusion, the purpose of this research work is to help automotive industry access the influences in improving their material handling system. Thus, a study on proper method and process to design material handling system and improvise in term of effective and efficient material handling system can contribute to various industries especially manufacturing industry in saving engineers time and company cost in developing new system. From a problem statement, a possible solution has been proposed by designing an integration between production system and material supply system using a proper design of material handling system. For simulation analysis, future work for this study will use Delmia v5 as simulation tool to undergo a virtual 3D simulation with ergonomic human movement in order to obtain the analysis result. By using the proper selection of method and tools, it is expected to have an efficient and effective automated material handling system. Lastly, the objectives are expected to be achieved by following the proposed methodology and design of experiment.

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