

# Simulation-Based Multi-Objective Optimization for Distributed Material Transportation System

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## Abstract

Material Transportation System (MTS) is required to move materials within a factory, warehouse, or other facilities. This study focused on AGV where the optimization of MTS is further studied. Although there is increasing demand in AGV control architecture, there is still unexplored potential in optimizing AGV performance measures. Applying AGVs in logistic factory may help in improving the efficiency in material flow and distribution among workstation at the right time and the right place. The aim of this study is to propose a simulation-based vehicle requirement analysis of AGVs in warehouse area with low mixed product variation. Simulations results show optimized number of AGV in warehouse area is achieved and succeed in produce short cycle time with high throughput.

**Keywords:** AGV, Multi-objective optimization, Material transportation system, Extension Rule.

## 1. Introduction

The material transport system (MTS) is one of the basic components in material handling system (MHS). The MHS includes the activity, equipment, or procedure that related to moving, storing, protecting and controlling of material in a system. Automated Guided Vehicles (AGVs) are widely used to transport materials for automated factories, container ports and other industrial workplaces [3]. Moreover, in a very competitive business scenario, they can increase productivity and reduce costs of warehouse transportation systems where warehousing is a part of information flow in logistics. In addition, AGV is made up of various functional units that are operating independently, thus each function may have its own virtue in achieving an objective function [4]. In some research, authors highlight that vehicle quantity directly affect the performance of the transportation system [13].

Eventually, an efficiency of moving products can be determined by the operation of transportation. Through the technique and management principle, it can improve a moving load, service quality, delivery speed, operation cost, the usage facility, and energy saving [12]. Other than that, utilization of AGV is effective for safety purpose with proper AGV guide path controller [14]. Therefore, AGVs in the factory logistic plays important mechanism which effecting production efficiency since, it provides flexibility in routing parts among element present in the system and energy consumption [9]. Thus, it takes care of moving raw materials or finished goods from or to warehouse and the production shop floor because any bottleneck or inefficiency in the factory can increase the productivity of the whole factory.

Basically, there are two categories of AGV control which are static and dynamic system [8]. The static control system is the

system in which the AGV runs the same route continuously then stop at the pickup or delivery point until the pallet is load or unloaded for the next point or delivery. The AGV only can continue the job until some other level logic asks to do so. Different with the static control system, dynamic control system allow the AGV to route to different point through different paths. The AGV routing is controlled by a host computer. In general, the dynamic control system is the most applicable control system for current automation industries whereby high demands overtime and efficiency of shop floor is a priority to maintain competitively. In many research articles, the dynamic control system for AGV has been discussed in [11] and [2].

This article focuses on the multi-objective optimization of multiple AGVs used for automated Warehouse based on low mixed product variation whereby the simulation-based vehicle requirement analysis for distributed MTS is proposed.

## 2. Methodology

The main aim for this research is to propose simulation-based vehicle requirement estimation for AGVs particularly in warehouse workplace. The loading capacity for AGV in this article is considered as a single loading. Although current research articles [5], [6], [4], and [10] mostly discussed multiple loading capacities, this article only focused on study certain performance measure by not considered regarding load capacity. The warehouse is divided into several zones for load and unloads pallets to the other zone. The simulation method in this article consist of two main actions: the estimation number of vehicles

and; simulation run as shown in Fig. 1. The simulation model was created by using Anylogic software. The objective is to estimate the number of vehicle required by a manufacturing system. Additionally, four main performance indicators are used to measure the efficiency of the proposed system. The performance indicators are transportation utilization, space utilization, system throughput and system cycle time.

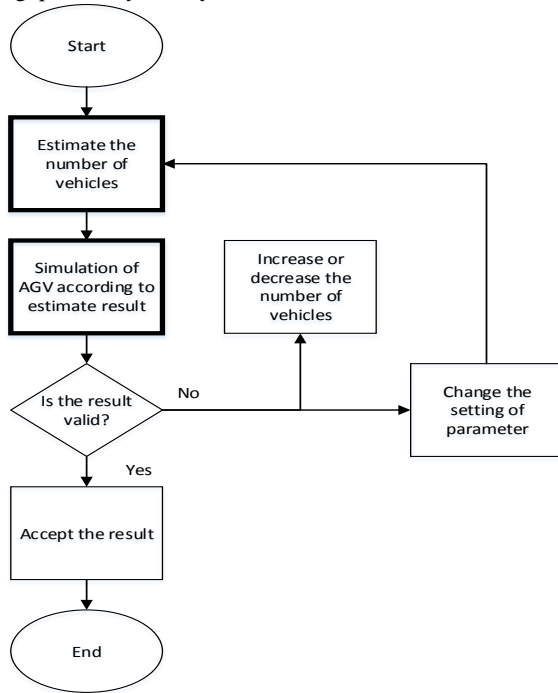


Fig. 1 The flowchart of the estimate and simulation approach

### 3. Experimental Design

Simulation has been carried out to study the effect of the number of AGVs to achieve two main objectives of this article which are to optimize the productivity of warehouse and improve response time for the whole system. To look forward both objectives, specific transportation performance metrics was identified in order to reach each objective. The first performance metric is studied to attain productivity in warehouse and second performance metric to measure an improvement of responsiveness of the system. These performance metrics are:

- i. System Throughput (STH)  
STH refers to the total quantity of manufactured goods that the system produces over specific time period. Basically, it measures the comprehensive range of system output.
- ii. Cycle Time (CT)  
CT is the total times spend for the finished product through delivery process in the warehouse. CT computation is defined in (1) where Tw is the total working hours per day and Th is the throughput.

$$CT = (Tw/Th) * 60 \text{ min} \tag{1}$$

The simulation model was programmed using Anylogic software [1]. This application software is able to model the behavior of individual agent and communication between each other, especially in logistic industry. Simulation model layout focused on the warehouse area which is it has several activities of distribution. The AGVs is the main transportation system is being used to transfer the pallets from one location to another location in the warehouse. However, there is still need a human employee to have an interface with the system. According to Cardarelli [2], the human employee has an opportunity in defining customs mission

to be performed. In this article, there are seven agent type including AGV. The functionalities of each agent was notified in Table 1.

Table 1 Functionalities of Agent in simulation

No	Agent	Responsibilities
1.	Operator	Unload pallets from supply trucks, scan the good at the reception area, match the pallet with orders in control zone and load the pallet on retail trucks.
2.	AGV	Take the pallet from each zone to transfer into another zone. In the storage area, AGV will take the pallets based on orders info.
3.	Input Truck	Receive pallets from unloaders and scan in the goods at reception area then transfer pallets to placement zone.

The warehouse storage is set empty when the model is initially executed. The supply truck delivers goods with inter-arrival time of every 5.5 minutes. Additionally, it takes 2.5 minutes to load / unload the pallets to / from the truck. The trucks consume 3 minutes to deliver to the warehouse. The capacity for incoming queue at the warehouse is up to 20 pallets at any one time. As the warehouse is initially empty, it is natural for the storage to become stocked. However, it is not the main concern for our study. The layout of the warehouse is separated into 6 zone which is dispatch zone, control zone, unloading zone, reception zone, placement zone, and storage zone. The movement of every pallet from zone to another zone is made by AGV. Besides that, when orders comes

take the pallet and send into control zone for order checking by an operator to match with orders. The speed for AGV is set at 8 km/hour with 90km/hour speed of supply truck was retaining through the simulation experiments as shown in table 3. In part of designing warehouse layout, all movement schedules must be clarified in the main agent properties. This to ensure the simulation run smoothly and all transportation used moves around the warehouse based on the designed flowchart. Through this experiment, the process flow within warehouse area is illustrated in Fig. 2.

Table 2: Specification in simulation experiment

Input Parameters	Value Range					
	Case1	Case2	Case3	Case4	Case5	Case6
No. of AGV	3	5	7	9	11	13
Input Truck	5	7	9	11		
Operator	6					

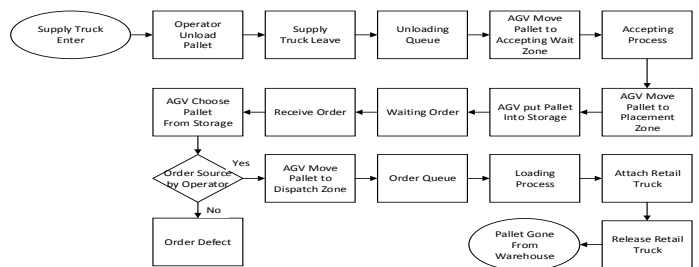


Fig. 2 Process flow in warehouse

Table 3: Speed setup at initial condition

Description	Speed (km/hrs)
AGV	8
Retail Truck	40
Supply truck	90

### 4. Simulation Results

The data was collected from simulation experiments. Fig. 3 and Fig. 4 show the statistical output from the changes in value range in different parameters. Based on the results, a different parameter

has produced different output. This output is in terms of system throughput and cycle time. The throughput performance is shown in Fig. 5 and cycle time performance in Fig. 6.

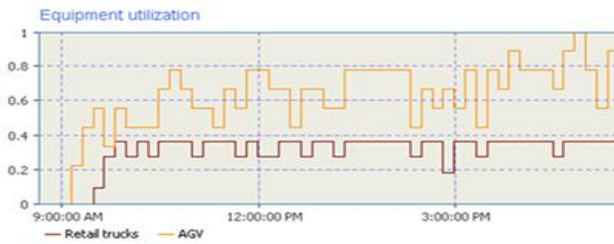


Fig. 3 Warehouse performance based on transportation utilization

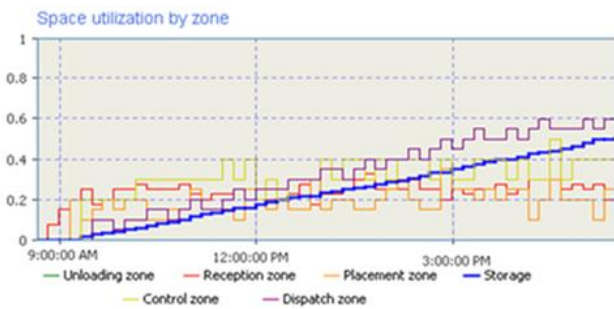


Fig. 4 Warehouse performance based on space utilization by zone

After the simulation was completed, data were analyzed and results were statistically presented. As mention before, the different parameter was used and output being produced is observed. Based on the results, different parameter has produced different output. This output is in terms of system throughput and cycle time. Fig. 5 shows that the system throughput increases when the number of AGV increases. Additionally, Fig. 6 shows that cycle time decreases when the number of AGV increases. However, there are no significant improvements in both indicators after 9 AGVs are deployed for transportation. This indicates that the system’s optimal transportation requirement could be achieved by having 9 AGVs in the system.

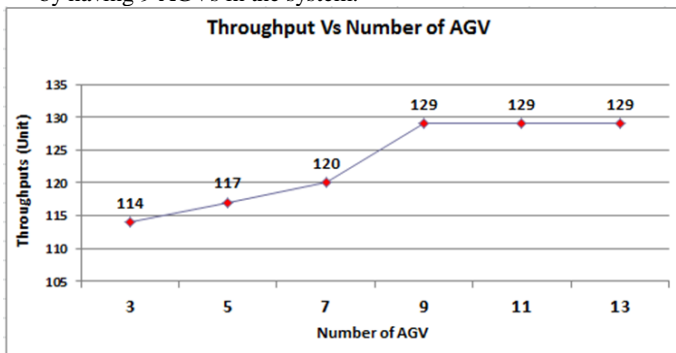


Fig. 5 The performance of throughput over number of AGV

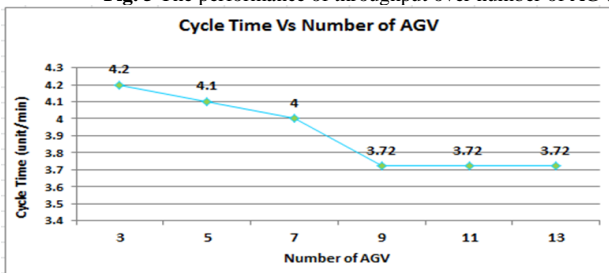


Fig. 6 The cycle time for the system over number of AGV

### Conclusions

In this study, a simulation-based vehicle requirement for AGV operation in the manufacturing industry is developed to establish

an AGV system in the warehouse area. The execution of AGV in the warehouse able to reduce cycle time for the whole system since that AGV is working based on programming setting. The result illustrates that the total cycle time can be reduced and system throughput can be increased with the optimized number of AGV is 9. In our future research, the effectiveness of the proposed system is to be examined by considering transportation assignment method in AGV operation.

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