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# Analysis of Automated Guided Vehicles in Ladder Layout Flexible Manufacturing System

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## Index Terms

AGVs, FMS, RGV, MHs, LDT

## Abstract

Automated Guided Vehicle system (AGVs) has been utilized for an extended period, particularly in the context of Flexible Manufacturing System (FMS). Among the different techniques for Automated Guided vehicle the research work focuses on the Rail Guided Vehicle (RGV) Technique. This method is commonly associated with Material Handling system (MHs) and is relatively straightforward to understanding. The study demonstrates how vehicles are identified to move parts between stations in the layout through the application of AGVs, with potential for application in related methods in the future. In addition, the data monitored by the AGVs process will be displayed on the runtime. Finally, this match with the desired result of output data to the AGVs progress.

## تحليل المركبات الموجهة آلياً في نظام التصنيع المرن ذو تخطيط السلم

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## الكلمات المفتاحية

AGVs, FMS, RGV, MHs, LDT

## الملخص

استُخدمت أنظمة المركبات الموجهة آلياً (AGVs) لفترة طويلة، لا سيما في سياق أنظمة التصنيع المرنة (FMS). ومن بين التقنيات المختلفة المستخدمة في هذه الأنظمة يركز البحث على تقنية المركبات الموجهة بالسكك الحديدية (RGV). هذه الطريقة عادةً بأنظمة مناولة المواد (MHs)، وهي سهلة الفهم نسبيًا. توضح الدراسة كيفية تحديد المركبات لنقل الأجزاء بين المحطات في التصميم من خلال تطبيق أنظمة المركبات الموجهة آلياً، مع إمكانية تطبيقها في أساليب مماثلة مستقبلاً. بالإضافة إلى ذلك، سيتم عرض البيانات التي ترصدها عملية أنظمة المركبات الموجهة آلياً أثناء التشغيل. وأخيراً، يتوافق هذا مع النتيجة المرجوة لبيانات الإخراج المتعلقة بنظام المركبات الموجهة آلياً.

## 1. Introduction

In earlier markets, companies focused on cost reduction and quality improvement to stay competitive. They primarily concentrated on manufacturing. However, in recent times, flexibility and dependability have become critical for success. To address this, companies began using Flexible Manufacturing Systems (FMS). FMS help break the trade-off between dependability and quality by reducing labor and process variability. They also offer multiple production routes to improve reliability and overcome maintenance and queuing issues. FMS increase overall productivity, improve product quality, and reduce vulnerabilities caused by unexpected order variations [1].

Automated Guided Vehicles (AGVs) have been widely adopted in flexible manufacturing systems, including industries such as automobile, food processing, wood working, and others. Several research papers have focused on the design and control aspects of AGVs [2].

The use of robots, specifically Automated Guided Vehicles (AGVs), is becoming a popular solution for improving efficiency and reducing costs in material movement systems. AGVs are commonly used in manufacturing plants, warehouses, distribution centers, and terminals to transport materials. They rely on various sensors such as optical, laser, magnetic, and camera sensors for navigation and obstacle detection. Modern AGVs have software-programmed tracks and can be customized when new stations and flows are added. Another essential automation tool in the industry is the Programmable Logic Controller (PLC) which allows the processing of analog and digital signals from sensors. Additionally, an articulated robotic arm can be mounted on the AGVs to transfer loads, further reducing the need for human operators [3].

## 2. Overview of Automated Guided Vehicles (AGVs)

Automated guided vehicles (AGVs) are mobile robots used in industries for transporting goods. The AGV market is rapidly growing, driven by factors such as flexible manufacturing systems, demand for customized AGVs, and industrial automation by SMEs. Current AGV systems are centralized, with a central entity handling tasks and coordination. However, the trend is now shifting towards decentralization, where each device in the system operates independently while working towards the same global goals. Decentralization is gaining attention due to the expansion of AGV fleets and the need for larger and more complex systems [4].

## 3. Importance of Ladder Layout in Flexible Manufacturing Systems

Companies producing mechanical components for final products must consider critical factors such as tight tolerances, short lead times, market changes, and cost pressures to remain competitive. However, achieving optimal performance in these areas can be challenging, as companies often have to make trade-offs. The degree of flexibility in manufacturing systems is crucial during the design phase, as it is necessary for both reactive and proactive firms. However, flexibility is not always advantageous and can affect profitability. There are cases

where flexible manufacturing systems underperform, the available flexibility remains unused, or flexibility is seen as a complication rather than an advantage. Customizing system flexibility can provide economic advantages but also reduces safety margins. Focused flexibility requires careful risk appraisal and the integration of different types of knowledge to obtain a competitive solution [5].

## 4. Performance variables

The performance of a FMS is influenced by several variables, such as the layout, machines, and optimization requirements. Some variables have a significant impact, while others have a minor effect. The variables include AGVs, processing time, material transfer rules, part processing sequence, buffer sizes, machine and equipment failure, and part characteristics. Based on previous studies and FMS characteristics, the selected performance variables for comparing AGV configurations are discussed.

AGVs are used in FMS to transport parts between different processing workstations. Parts are loaded onto AGVs at load/unload points near the workstations and then moved to another load/unload point to be unloaded for processing at the next workstation [6]. The load/unload time (LDT) of parts on/from AGVs affects the transfer of parts in the system. LDT depends on factors such as part geometry, weight, safety considerations, and equipment used. Specialized equipment can minimize LDT to some extent, but it cannot be completely eliminated. Therefore, LDT is a crucial factor affecting system performance [7]. Machine failure is another important issue in FMS. The high setup cost involved makes it necessary for machines and equipment to work without interruption. Machine failure, including scheduled and unscheduled occurrences, can cause production to halt and lead to heavy losses. Three levels of machine failures considered are: no failure, 2% failure, and 4% failure [6]. Since FMS processes parts of mid volume and variety, processing time varies within a part family. This variation follows a probabilistic distribution, such as deterministic, Erlang, or exponential distribution. The study considers three levels of processing time distribution with a mean of 10 minutes [6]. AGV speed is a crucial factor in the performance of the system. It facilitates faster parts transfer between P/D stations. AGV speed is limited by factors like inertia and centrifugal force on curved paths. The study considers three levels of AGV speeds: 35, 40, and 45 m/min [7].

## 5. Literature Review

Summary of various studies in this subject area. (Ravindra Kumar, & other), In this paper compares three commonly used AGV configurations (single loop, tandem, and tandem loop) in terms of load/unload time, machine failure, processing time distribution, and AGV speed. Simulation and Taguchi methods were used for the study and statistical analysis. The study concludes that no single AGV configuration is suitable for all manufacturing environments [7]. (Ilias Vlachos, & other), study explores the impact of Autonomous Guided Vehicles (AGVs) and the Internet of Things (IoT) on Flexible Manufacturing Systems (FMS). It examines the integration of AGVs with IoT in a manufacturing company and uses socio-technical

systems theory to elaborate on the concept of FMS. Key themes include AGVs in warehouse systems, scheduling and routing, human-machine interface, and integrating AGVs with IoT. The case study demonstrates the steps to create smart, flexible manufacturing systems using AGVs. The study concludes with recommendations for implementing Industry 4.0 in manufacturing companies [8]. (Rundong Yan, & other), A study has developed a new model using Coloured Petri Nets to simulate a multi-load Automated Guided Vehicle system. The model aims to understand the advantages and performance of the system. The study addresses multiple key questions, including whether increasing the load capacity of the multi-load AGVs continuously improves system performance and if there is an optimal load capacity. The research findings show that increasing the load capacity initially improves efficiency, but effectiveness decreases beyond a certain value. Additionally, a system with flexible loading and unloading points performs better with a multi-load AGV [9]. Automated guided vehicles (AGVs) are a vital element of modern logistic transport systems. They are widely utilized in Europe, typically operating under centralized control systems. However, there is a notable trend towards decentralized systems, where AGVs have the capability to autonomously make decisions, thereby improving flexibility, robustness, and scalability. (M. De Ryck, & other), paper aims to provide a comprehensive overview of AGV-related control algorithms and techniques, covering early stages, recent systems, and those with high potential [4]. In paper (Jaiganesh .V, & other) describes a customized AGV with a material transfer system on top and a driving device below, allowing it to perform specific material handling tasks. Once the program is inputted into the control device, the vehicle operates autonomously. Proximity and photo sensors enable the AGV to detect movement and materials, while a magnetic tape system ensures optimal flow path. The battery-powered AGV charges automatically and utilizes inductive power transfer methods for enhanced performance [3]. (Hameedah Sahib, & Intan Z.) AGV routing problem involves finding the shortest path between two stations. AGVs are widely used in transportation systems. Static routing follows pre-defined routes, while dynamic routing allows for more flexibility. This paper introduces AGV routing and compares various shortest path algorithms. Real-time AGV routing using a local position system (LPS) in a labview environment is also achieved [10].

### 6. Analysis of Automated Guided Vehicles

This section covers basic relationships, tenets, and approaches in studying AGV systems.

There are numerous methods and techniques utilized in analyzing AGVS systems. In this paper, tabular and graphical techniques were employed to develop a conceptualization and analysis of such systems. From-to charts are versatile and helpful for displaying material flow information, such as the number of deliveries, distances between points, and volume of product flow. Graphical techniques like flow diagrams also visualize the moves and convey the same information as from-to charts. These techniques aid in understanding material flow rates,

operation times, and overall performance in an AGVS system [11]. The procedures listed below can be used to measure and analyze autonomously guided robot systems: The graphic shows that.

**First step** is to calculate the individual distances between each station. The following formula (1) is applied in order to calculate these distances:

$$D_{i\ to\ j} = \sum_{i=1}^{j=n} d_{ij} \quad (1)$$

Where  $D_{i\ to\ j}$  = Total distance from i to j,

$d_{ij}$  = length or distance between i to j,

n = number of cells in the layout.

**The second step** is to populate a from-to chart or matrix with the distances and parts, where the number of pieces and distances are assigned to the stations that have movement between them, whether it's for loading or unloading only. This is illustrated in table (1) as follows:

Table (1) matrix of the distances and parts

To:\From:	1	2	3	... n
1	-	$P_{12}/D_{12}$	$P_{13}/D_{13}$	$P_{1n}/D_{1n}$
2	$P_{21}/D_{21}$	-	$P_{23}/D_{23}$	$P_{2n}/D_{2n}$
3	$P_{31}/D_{31}$	$P_{32}/D_{32}$	-	$P_{3n}/D_{3n}$
n	$P_{n1}/D_{n1}$	$P_{n2}/D_{n2}$	$P_{n3}/D_{n3}$	-

Where  $P_{ij}$  = number of pieces to be transported between the stations.

**The third step** is involves preparing a from-to chart. Now, a flow diagram can be drawn by depicting stations as circles connected by arrows indicating the direction of movement, as well as the number of parts transferred from one station to another, and the distances the vehicle will travel while carrying the parts to reach the next station (Fig1).

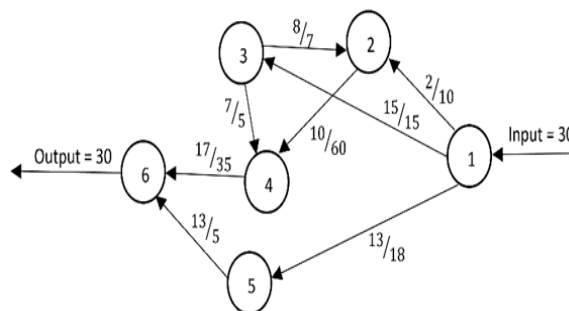


Figure1: Diagram of stations as circles (from..To)

**The fourth and final step** involves calculating some important variables in the analysis process of autonomously guided robot systems, including the following:

Total Cycle Time per Delivery per Vehicle refers to the overall duration it takes for an automated guided vehicle (AGV) system to complete a full cycle of delivering goods or materials from a single AGV vehicle to the final destination and returning to the starting point. The total cycle time is calculated by summing up the time taken for each step of the process, including loading the materials at the initial point, transporting the materials between points, unloading the materials at the destination point, and returning to the starting point. is given by formula (2):

$$T_c = T_L + \frac{L_d}{v_c} + T_U + \frac{L_e}{v_c} \quad (2)$$

Where

$T_c$  = delivery cycle time, min/del;

$T_L$  = time to load at load station, min;

$L_d$  = distance the vehicle travels between load and unload station, m (ft);

$v_c$  = carrier velocity, m/min (ft/min);

$T_U$  = time to unload at unload station, min; and

$L_e$  = distance the vehicle travels empty until the start of the next delivery cycle, m (ft).

1. The available time per hour per vehicle refers to the total time that a specific vehicle in an automated system is available for operation within a given hour. It represents the duration during which the vehicle can actively perform tasks, such as transportation, loading, and unloading, without being idle or undergoing maintenance. can now be expressed as formula(3):

$$AT = 60 A F_t E_w \quad (3)$$

Where

AT = available time, min/hr per vehicle;

A = availability;

F<sub>t</sub>= traffic factor (range between 0.85 and 1.0), and

E<sub>w</sub> = worker factor.

2. The rate of deliveries per vehicle refers to the number of deliveries that a specific vehicle in an automated system can complete within a given time period. It represents the efficiency and productivity of the vehicle in terms of the number of deliveries it can handle as formula (4).

$$R_{dv} = \frac{AT}{T_c} \quad (4)$$

Where

$R_{dv}$ = hourly delivery rate per vehicle, deliveries/hr per vehicle.

3. The workload refers to the amount of tasks, activities, or responsibilities assigned to an individual or a group within a specific period. In the context of an automated system, the workload typically refers to the amount of work or tasks assigned to the vehicles or robots involved in the system's operations which can get as formula (5).

$$WL = R_f T_c \quad (5)$$

Where,

WL= workload, min/hr;

$R_f$  = specified flow rate of total deliveries per hour for the system, deliveries/hr.

4. The number of vehicles required to accomplish this workload refers to the quantity of vehicles necessary to effectively complete the specified workload or tasks. In other words, it signifies the number of vehicles or means of transportation needed to carry out the designated tasks and operations within the mentioned workload as formula (6).

$$n_c = \frac{WL}{AT} = \frac{R_f}{R_{dv}} \quad (6)$$

Where,  $n_c$ = number of carriers required.

### 7. Case study:

A comprehensive analysis of a flexible manufacturing system is currently underway. The system is structured in a ladder configuration, as illustrated in Fig(2) below, and incorporates a rail-guided vehicle system for the transportation of components between various stations within the layout. All workpieces are introduced into the system at station 1, subsequently transported to one of three processing stations (2, 3, or 4), and thereafter returned to station 1 for unloading. Upon being loaded onto the rail-guided vehicle, each workpiece remains on the vehicle for the entirety of its duration within the flexible manufacturing system. The loading and unloading durations at station 1 are each quantified as 1.0 minute. The processing intervals at the alternative stations are delineated as follows: 5.0 minutes for station 2, 7.0 minutes for station 3, and 9.0 minutes for station 4. The system achieves the following hourly production rates: 7 components at station 2, 6 components at station 3, and 5 components at station 4. In this analysis, we shall formulate the From-To Chart for trips and distances utilizing a format analogous to that presented in the Table. Additionally, a flow diagram will be constructed to represent this data. Furthermore, the From-To chart developed in this context will serve to ascertain the requisite number of rail-guided vehicles necessary to fulfill the operational demands of the flexible manufacturing system, given a vehicle speed of 60 m/min and an anticipated traffic factor of 0.85. It is assumed that reliability A is 100% and efficiency E is 1.0.

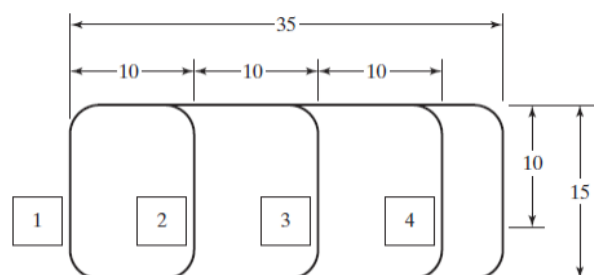


Figure2: ladder layout for stations

In this our case, there are important three requirements, which are:

Firstly, is develop the distances from the FMS layout.

- Distance from 1 to 2:  $10 + 10 + 10 = 30$  m
- Distance from 2 to 1:  $5 + 10 + 5 = 20$  m
- Distance from 1 to 3:  $10 + 20 + 10 = 40$  m
- Distance from 3 to 1:  $5 + 20 + 5 = 30$  m
- Distance from 1 to 4:  $10 + 30 + 10 = 50$  m
- Distance from 4 to 1:  $5 + 30 + 5 = 40$  m

From-To chart Table (2):

Tabel (2) matrix of the distances and parts

To:	1	2	3	4
From: 1	0/0	7/30	6/40	5/50
2	7/20	0/0	-	-
3	6/30	-	0/0	-
4	5/40	-	-	0/0

Secondly, is develop the flow diagram for this data as the illustrated in Fig(3):

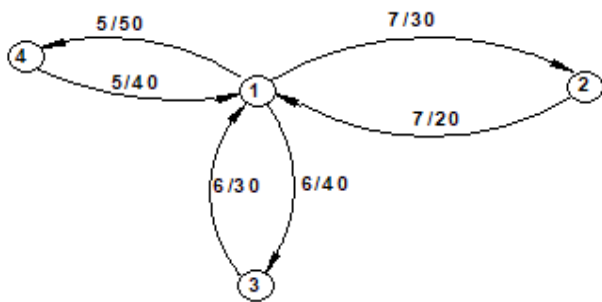


Figure3: Diagram data for stations

Finally, the From-To chart has been formulated to ascertain the requisite quantity of rail-guided vehicles necessary to fulfill the demands of the flexible manufacturing system.

$$Ld = \frac{7(30 + 20) + 6(40 + 30) + 5(50 + 40)}{7 + 6 + 5} = 67.7 \text{ m}$$

$$Le = 0$$

Mean duration for handling and processing =

$$1.0 + \frac{7(5.0) + 6(7.0) + 5(9.0)}{7 + 6 + 5} + 1.0 = 8.78 \text{ min.}$$

$$Tc = 8.78 + \frac{67.7}{60} + \frac{0}{60} = 9.91 \text{ min.}$$

$$R_{dv} = \frac{60(0.85)}{9.91} = 5.15 \text{ pc/hr per vehicle}$$

$$nc = \frac{7 + 6 + 5}{5.15} = 18/5.15 = 3.5 \rightarrow 4 \text{ vehicles.}$$

### 8. Conclusion:

This scholarly investigation concentrated on the implementation of Automated Guided Vehicles (AGVs) within Flexible Manufacturing Systems (FMS) to enhance the efficiency of material handling systems by optimizing the processes of loading at the pickup station, minimizing travel time to the drop-off station, facilitating unloading at the drop-off station, and reducing the empty travel time of the vehicle between successive deliveries. The methodology employed involved the application of specific mathematical equations for data analysis, with a distinct focus on the Rail Guided Vehicle (RGV) Technique. A comprehensive case study was conducted utilizing these equations to ascertain the extent of distance traversed by the vehicles. Furthermore, the From-To chart developed in this study is utilized to ascertain the requisite number of rail guided vehicles necessary to fulfill the operational demands of the flexible manufacturing system. In summation, this research significantly contributes to the comprehension of how methodologies such as AGVs can augment efficiency within material handling systems. Additional investigation and refinement of these methodologies may result in considerable progress in the enhancement of handling systems, thereby benefiting industries that aspire to achieve greater efficiency and cost-effectiveness. Based on the analytical data, it was determined that the distance traveled by the vehicle between the load and unload stations is 67.7 meters. Additionally, it was ascertained that a total of four rail-guided vehicles are required to adequately satisfy the operational requirements.

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