# Automated Guided Vehicle Based Material Handling System: A Survey

**Chayan Dey[1], Abhishikta Mukhopadhyay[2], Saptarshi Sarkar[3]**

[1]Department of Electronics & Communication Engineering, Techno India University, West Bengal, India
debc8922[at]gmail.com

[2]Department of Electrical Engineering, Institute of Engineering & Management, Salt Lake, Kolkata
abhishikta999[at]gmail.com

[3]Department of Electronics & Communication Engineering, Institute of Engineering & Management, Salt Lake, Kolkata
sarkarsape[at]gmail.com

**Abstract:** ***The paper is intended to provide a literature survey of AGV based material handling system. Out of different factors related to the design and operation performance of AGV in any manufacturing unit, four major factors, viz., throughput, unit load, flow path design and fleet size have major roles. The study focuses basic methodologies followed by objective function and problem areas of the material handling system. It emphasizes studies done by different workers during the last three decades associated with the topic of present-day interest. AGV systems are gaining increasing acceptance in modern manufacturing facilities mainly owing to the versatility they offer. Our survey reveals that AGV based material handling system is an extraordinary challenging field of open area of research with many lines for further investigation.***

**Keywords:** Automated Guided Vehicle, Navigation, Material Handling System, Reconfigurable AGV System

## 1.Introduction

An automated guided vehicle (AGV) is an unmanned self-propelled vehicle used for transporting a payload without real-time human assistance. Since an AGV operates with controlled navigation, it can be used to eliminate the need for direct operator involvement and so reducing the risks related to operator-introduced error during movement which is typically along a guided path or route laid out in or on a facility floor, distribution center, warehouse, etc. The AGV can use a human controller interface like a joystick, magnetic sensors, optical sensors, electrical field sensors, inertial guidance, global positioning system (GPS), and laser guidance for navigation along the path. The guidance system can be applied to dictate a precise and repeatable path for the AGV to follow, while the sensor systems can give real-time updates to encroach upon the AGV's path of travel. AGV has been defined [1] as an automatic load carrier to transfer objects from one location to another. AGVs are the fundamental element for doing flexible transport tasks in industrial production [2, 3]. In recent years, AGVs are increasingly used in industries for delivering work pieces at specified locations. Villagra et al. [3] pointed out that in order to perform the common tasks between pickup and delivery stations, AGVs should get around between stations and achieve precise pick-up and drop operations. Navigation between two stations is termed as point-to point navigation. In this survey, we have made a comparison of the work done by different authors on AGVs giving priority to the advantages in various applications of AGV and issues associated with the material handling system. The flexibility and complexity of AGV systems suggest the requirements of the design effort and the routeing and scheduling system grow. Through this survey we have suggested the relevant literature which may be used suitably for the system design, routeing and scheduling, as well as an outline for the justification and implementation of AGV systems for all practical purposes.

## 2.Navigation of the Vehicle

The main problem regarding AGV system is the navigation of the vehicle. Arkin et al. [2] considered elaborately the simulation studies, motivation and the results of the experiments giving priority to the feasibility of migrating schema-based navigation into a Flexible Manufacturing System (FMS). The main advantage of this navigation is it gives a framework, which is adaptable conveniently to the manufacturing industry. It further makes simple of the navigation problem restricting their paths to preselected routes as well as uses the diversity of sensors strategies and relevant motor actuators for particular domain for limiting the drive path problems. However, it demands significant restructuring of the workplace for the AGV to be useful. For successful operation, it requires a considerable amount of knowledge for both environmental and behavioral. The necessary changes in the production line for the AGVs demand a huge expense, which is required to keep in mind for proper planning of its implementation [3]. The application is important and simple as it has free navigation capability for getting a higher operational flexibility and able to adapt for changing production configurations and economic sensor systems to get navigation and obstacle avoidance functions [4]. But it is largely limited by the IR-reflectors and by a code-mark. Again, they used inexpensive sensors causing less exact measurements. Further, the energy consumption of the transport is high [5]. Schulze et al. [6] concluded that significant technological developments contributed to the increasing of the attractiveness of AGV systems for the users for variety of purposes. They mainly attempted with the modularity, the standardization, the energy concept, the navigation system as well as for the purpose of automation of series vehicles and the safety system.

With the development of the technology many advantages have noted, e.g., it can reduce complexity of the modules as well as the establishment of compatibility between different AGV'S producers. The primary task of the navigation systems is to lead the vehicles after given strategies properly to their destination. The problem of the system is it need different variety of maintenance and part logistics and it is essential to guide by optical or inductive guidelines. The disadvantage is notable particularly for inflexibility concerning the modification of the routing and the requirement of installations on or in the ground [7].

## 3.AGV Behavior

There are three primary points that determine the Automated Guided Vehicle behavior discussed. The first one is the routing algorithm, which computes the overall task execution time and also the minimum global path of each AGV following a topological map of the warehouse. The second one is the local path planning algorithm while the third is an auto localization algorithm. Before sending the final paths to the robots, the router developed was able to solve traffic jams and collisions. They use only simulation and algorithm not tested and done in real life situations [8]. On the other hand, Takenaga et al. [9] investigated the method to run the vehicle through a lane based on vision feedback eliminating collision or collapse with obstacles to provide intelligence for a number of AGVs through dynamical processing [9]. The advantage of this technique is it has vision feedback avoiding collision or collapse with obstacles. It further has sensor to provide feedback especially during trouble shooting. The drawback of this technique is it requires mounted PC which can be treated as an agent and this makes the AGV highly expensive, fragile and bulky. Suitable application is thus limited owing to the mounted PC on top. Again, power consumption is a major issue in this method. It demands special skill worker to operate successfully [10]. Takenaga [9] pointed out the advantages of the navigation part that consists on calculating and following the trajectory to reach the goal obtained from the plant layout and thereby recalculated to avoid the non-modeled obstacles sensed during the navigation. However, this type of coordination is weak as it depends on the mapping of the environment [11]. Kelly et al. [12] developed a virtually infrastructure-free AGV which is coupled with a highly capable trajectory generation algorithm. Further the system produces four visual servos which can guide the vehicle constantly in a few contexts.

## 4.AGV Control Factors and Supervisory

Control factor arises in many works with AGVs for variety of reasons. Espufia et al. [13] worked on transport planning and scheduling utilizing AGVs, integrating with CIM environments in the factory plant. These approaches are linked to decision making with the transport system and so integrated and coordinated with the overall plant decision-making. In addition, the system can be used for evaluating the performance of specific transport system in different production scenarios, hence giving to the user the production cost in terms of productivity, production time, equipment idle time, etc. related to this specific configuration. However, the approach has several draw backs related to distance covered and availability of the AGVs in the evaluation of the influence of transport operations [13]. Moreover, the vehicles are powered by batteries and so to control battery load maintaining the battery consumption and energy use is a huge factor. Besides, mathematical complexity of the scheduling model and stochastic is another important issue.

Lozoya et al. [14] in another similar approach used real-time wireless control that gives the company information within precise time-bounds. They followed statistical estimation for making the algorithms by evaluating the vehicle's travelling time and path deviation. AGVs control systems for all practical purposes may consist as an external controller sending and receiving through a wireless network wherein the control commands to the vehicle. By making use of real-time wireless control, it is limited in many ways as it depends on the connectivity and range of wireless. Furthermore, radio channels and the medium access control (MAC) generate random communication delays that exhibit severe performance problems. Some control technique for actual need was proposed by Rose et al. [15] wherein the control method was implemented. Fauadi et al. [16] also suggested dynamic task assignment of autonomous AGV System based on Multi Agent Architecture. This is done for testing the capability of the AGVs and to control the material handling activities [17]. Sen et al. [1] concluded that the supervisory system is basically the traffic controller that interfaces the AGVs fleet with other activities in the factory. It demands to utilize various algorithms which lead to complexity and trouble arise when trouble shooting. It needs special skill and train employee or personnel for operating properly. In the production line it also requires high expensive to implement detail design [17, 20-22]. It affects the maneuverability and flexibility sometimes. This AGV needs wireless connection which has a limited range [18, 19, 23-25].

## 5.Role and Challenges

AGV is the simple machine used to move a part or material from one defined location to the next. It is not only used in the manufacturing industry but also in the military, theme park, healthcare and transportation logistic [26, 27]. It can be interfaced with other modules of flexible manufacturing system like robots, CNC machines, automatic storage and retrieval system, etc [28, 29]. Its delivery method is predictable while avoiding interference with building factors. It can operate for a long time, without stop and can be widely used as it can be operated in extreme temperatures conditions and hazardous environments [19, 30-32]. Though AGV provides many advantages to industries, there are some strong disadvantages also. The main disadvantage is the inflexibility for the modification and changing of the routing and the installations [33, 34].

## 6.Movement, Packing and Storing of Subsystems

Material Handling is primarily a science of involving the movement, packing and storing of subsystems in different forms. Material handling function includes movements in vertical, horizontal or combination of both for all types of material fluid, semi fluid and discrete items and of movements needed for packing and storing [35-38]. The material handling function is assumed as one of the most important activities of the production function as out of total time spent by the materials inside the plant area. About 20% of the time is utilized for actual processing on them while rest 80 % of the time is used to move from one place to another, waiting for processing or finding place in sub-stores. Further, about 20 % of the total production cost is traceable as material handling cost. The relative percentage changes according to the type of product, plant layout, production method, availability of resources like men, machine etc. In most of the manufacturing systems, the material handling system plays a vital role as it is mainly responsible for providing the right material at the right place and right time [39, 40]. A poorly designed material handling system creates problem with the efficient operation of a manufacturing system and in the long-term it may lead to a substantial loss in productivity [41].

## 7.Reconfigurable AGV System

An automated guided vehicle system may include a plurality of AGV arranged in a predetermined relationship with respect to each other for supporting a payload. Each of the AGV has a plurality of rollers extending from the automated guided vehicle and engaging a ground surface [42]. Furthermore, at least one locator extends from the AGV and engages the payload. Each of the AGV has an on-board controller arranged within a housing thereof, with one on-board controller acting as a master controller and the remaining of the on-board controllers acting as slave controllers. The master controller communicates with the slave controllers to maintain position and speed control of each automated guided vehicle in both a lateral and a longitudinal direction. Furthermore, the slave controllers send feedback information to the master controller [43]. A scheme of reconfigurable manufacturing system followed for practical purposes is shown in Figure 1 while in Figure 2 we have shown the different steps followed in an actual technique of reconfigurable manufacturing system [44].

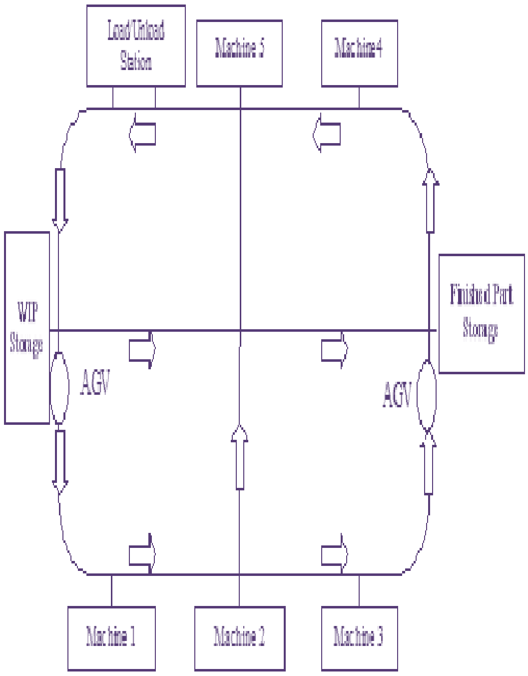


**Figure 1:** Scheme of reconfigurable manufacturing system

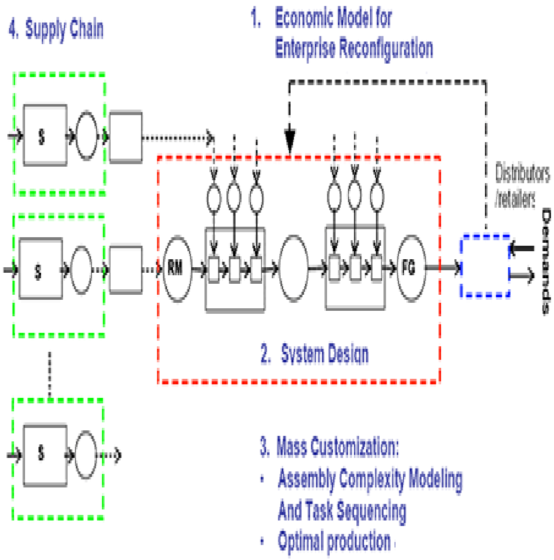


**Figure 2:** Different steps in an actual technique of reconfigurable manufacturing system [44]

An AGV system includes a plurality of automated guided vehicles arranged in a predetermined relationship with respect to each other with a view to support a payload. Each of the automated guided vehicles has a plurality of rollers extending from the AGV and engaging a ground surface. Furthermore, at least one locator extends from the AGV and engages the payload. Each of the AGV has an on-board controller arranged within a housing thereof, with one on-board controller acting as a master controller and the remaining of the on-board controllers acting as slave controllers. The master controller communicates with the slave controllers for maintaining the position and speed control of each automated guided vehicle in both a lateral and a longitudinal direction. In the system, the slave controllers send feedback information to the master controller.

### 7.1. Industry Trends

Material Handling Equipment Market size was over USD 130 billion by 2017 and is anticipated to grow at a CAGR of over 5.5% from 2018 to 2024 [45].Rising demand for sophisticated automated systems coupled with the ever-increasing labor costs is anticipated to contribute to the material handling equipment market growth over the forecast timeline. The demand for automated pick & place robots is on the rise since these systems can be controlled remotely, offering features such as precise operational capability, contributing to the material handling equipment market demand. There are high operational costs associated with the use of industrial trucks to ensure their smooth operations.

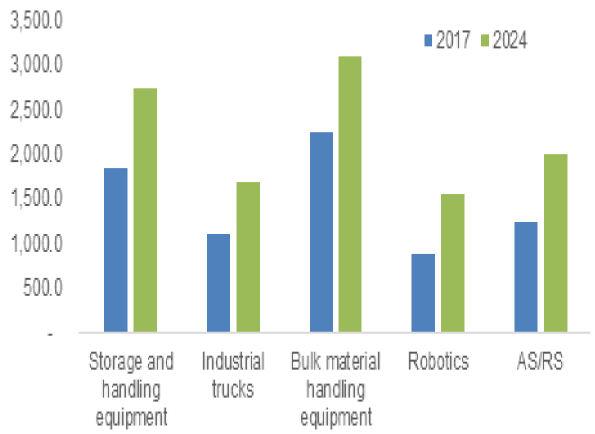


**Figure 3** Germany Material Handling Equipment Market, By Product, 2017 & 2024; USD Million [45]

## 8.Discussion

An AGV is a portable robot that follows markers or wires in the floor or uses vision, magnets or lasers for navigation [46]. They are frequently used in industrial applications for the requirement of movement of materials around a manufacturing facility or warehouse. In present century, the uses of automated guided vehicles are becomingly more common in the manufacturing industries particularly in larger manufacturing companies [47-49]. The usages of AGVs are increasingly taking major role not just for handling material but also for multi-tasking jobs associated with the manufacturing industry. We have elaborately discussed in the paper, the issues related to automated guided vehicles in the automated manufacturing industry when dealing with AGVs in the industries [50-52]. When the force exceeds the baseline force, the associated locator or the automated guided vehicle carrying the associated locator is moved in a direction that reduces the force on the locator to less than or equal to the baseline force [53, 54].

Areas of applicability will become apparent from the description provided herein [55, 56]. It should be mentioned that the specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure. Different methods related to AGVs have been proposed by scientists in manufacturing industries. Some of them have successfully been implemented in the industries today which have their both merits and demerits [57, 58]. We have mentioned some relevant factors when dealing with AGVs in the computer applications manufacturing industries. The main issue can be categorized into three major headings which are navigation, control and supervisory. It is believed that by pointing out these issues, future research and development can be done for solving the problems facing by AGVs users especially in the manufacturing industries [59].

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## Author Profile

**Chayan Dey** is a full time researcher and faculty at the Electronics & Communication Engineering Department of Techno India University, West Bengal. He keeps a keen interest in research and training aspiring students. He has published many research articles in various National and International Journals. His research work covers a wide spectrum area like Industrial Engineering, Applied Electronics, Non-conventional energy development procedural feasibility and analysis and many more.

**Abhishikta Mukhopadhyay** is a brilliant student with a very good academic record, has completed her B.Tech in Electrical Engineering from one of the most prestigious institute of the country, Institute of Engineering & Management, Kolkata in the year 2020. She keeps a keen interest in doing research work and pursuing higher studies in the field of core engineering.

**Saptarshi Sarkar** is a hardworking and motivated undergraduate student from Institute of Engineering & Management, Kolkata. He is pursuing his B.Tech in Electronics & Communication Engineering.