CATION OF AMR-TYPE MATERIAL HANDLING IN LOGISTICS

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***ABSTRACT**: One of the key trends of the 4.0 industrial revolution is the digitalization of processes and the resulting use of loss reduction solutions (Big Data concept, Lean 4.0 tools, etc.). Material handling within various types of production and service processes has been mostly achieved in the last decades by human-operated forklift trucks. Nowadays, the use of AGVs and AMRs is gaining importance, as their application in many cases allows for more efficient company operations. A comparison of these transport solutions from different points of view and their potential applications in the field of logistics are summarized. The knowledge presented in this thesis can serve as a basis for decision support for corporate investments and for logistics research.*

***KEYWORDS**: AGV, AMR, digitalization, 4.0 industrial revolution*

1 INTRODUCTION

Nowadays, automation is becoming increasingly important in logistics process planning because of its many advantages. It is clear that automation is no longer limited to production processes, but also applies to complementary processes. The handling of piece goods or palletized unit loads is done by forklift trucks and, in most cases, by human drivers.

As an introduction to this publication, a brief overview of the historical development of material handling is given. In the early days manual handling was the only method, which was predominantly human, but there were also many cases of animal handling. The oldest method of transport is purely human. This method is still without alternatives today for short distances and small weights and sizes of goods (Skilling et al. 2016).

The next step in the evolutionary history was the use of simple machines, such as the water crane well, still using pure human power, but with some kind of power boost.

In the handling of materials, some form of natural force such as wind power or waterpower then appeared in addition to the use of human power. The former type of force is still used today in an upgraded version in pneumatic systems, for example, in the food industry (Fitzpatrick et al. 2005). Similarly, the use of water or other fluids is used in hydraulic systems, mostly supplemented by electronic devices (Minav et al. 2013).

The next step in material handling is the automated material handling. Initially, the pneumatic and hydraulic systems mentioned above were used, followed by steam engines during the first industrial revolution, and then, during the 20th century, by the use of electricity for material handling (Devine, 1983).

With the advent of mechanized material handling came the mobile handling units and with them the lifting cranes. Although manual lifting is still used today, different types of forklift trucks are used for heavier and larger loads for lifting and transportation. Over time, specialized types have also appeared, such as the sliding forklift truck or the articulated mast truck (Conger, 2022). However, it is also noticeable that the automation that is nowadays being talked about has only been extended to a small extent to the field of transport.

The idea of automated material handling was first mooted in the 1960's (Müller, 1983 & Hammond, 1986). This is when the so-called AGVs (Automated Guided Vehicle) were developed. These devices could only follow a certain line. In the 2000s, AGVs appeared that no longer used physical tracks. These could determine their position using some kind of positioning sensor.

In the 2010s, AGVs were joined by AMRs (Autonomous Mobile Robots), which do not use any external infrastructure, but only on-board sensors.

This article describes the main differences between AGVs and AMRs, highlighting the types and characteristics of each, followed by application examples. The article also covers an outlined method for choosing the right type of material handling system.

2 DIFFERENCES BETWEEN AGV AND AMR

This chapter describes the differences between AGV and AMR systems in use today. The comparison is based on Table 1 (Schmidt, 2021). The criterias were chosen based on the most important factors for companies by choosing such a device.

Table. 1. Comparing AGV and AMR

Type	AGV	AMR
Maturity	High	Medium
Medium to high payload	Yes	Under development
On-site installation	Long	Short
Infrastructure modification	Needed	Not needed
Workflow modification	Difficult	Easy
Flexibility	Low	High
Scalability	Lower	Higher
Human-robot collaboration	Limited	Expansive
Design	Bigger	Smaller
Operating costs	Lower	Medium
Maintenance	Easier	More difficult

2.1 AGV

AGV navigation predominantly uses some kind of physical infrastructure (track), such as a magnetic stripe or optical stripe. The key feature of this tracking is that the mobile robot can only follow this path. Changing the route is only possible by changing the track, which is considered inflexible given today's rapidly changing transport needs.

The programming of the route is limited to following the path. Another limitation is that in many cases an external cable is required to charge the battery on only few charging stations within the fixed routes.

The inflexibility of route modification also applies to relocation. If the vehicle is to be relocated, the program must be adapted to the new route.

The situation is somewhat better if a virtual track is used instead of a physical track. In this case, a LIDAR sensor is one of the known methods which can be used. Other methods can be a LaserScanner, Camera based systems in combination with indoor location (commonly WLAN, Bluetooth) and outdoor GPS/GLONASS. The LIDAR sensor uses special mirrors placed in the room as reference points, so it still requires external infrastructure. In terms of programming, it is the virtual path that needs to be set up, which is more flexible than in the case of a fixed physical path. However, relocation is no longer flexible, as moving the AGV also means relocating the external infrastructure, which is a time-consuming process to set up again. With a physical track, it is still feasible to move the AGV from one location to another, but with a virtual track it is more difficult.

One of the safety features of automatic moving systems is collision avoidance, which can only be achieved by slowing down or possibly stopping the forklift. If the forklift were to leave the track, it would most likely not find its way back to the original route and human intervention would be required.

2.2 AMR

Autonomous mobile robots are industrial robots that use a decentralized decision-making process for collision-free navigation to provide a platform for material handling, collaborative activities, and full services within a bounded area (Fragapane et al. 2021).

The essence of AMR is that it does not use any external infrastructure. Accordingly, the on-board sensing is designed in such a way that it can sense its environment and filter certain information based on the sensed data.

Navigation is based on various on-board distance sensors and cameras. The cameras not only allow the vehicle to monitor the route, but also to distinguish obstacles. Thus, the system is able to detect static obstacles, such as a stationary box, and dynamic obstacles, such as the presence of a person. By detecting the obstacle, it can also modify the route in such a way that the transport time is increased as little as possible.

Another feature of AMRs is that, since they do not use external infrastructure, they can be flexible to modify the route and relocate the mobile robot, saving significant time and cost.

AMRs also allow easier charging due to the flexibility of route planning. The mobile robot can move to a predefined location and connect to the predefined contacts.

3 AGV AND AMR APPLICATION EXAMPLES

3.1 AGV application examples

Our first example depicted here of an application is the AGV created by the Fraunhofer IML Institute in Germany in collaboration with BMW, which the creators have named Smart Transport Robot. This AGV can lift and transport trailers containing unit loads. It is navigated in a hybrid way, partly by a progress sensor and partly by radio transmitters placed in the space. An example is shown in Figure 1 (Fraunhofer IML, 2016).

Fig. 1. Smart Transport Robot (Fraunhofer IML, 2016)

The second example is a solution from Symbotic. This mobile robot is combined with a fork gripper. This mobile robot is used in a store of the Walmart chain. The example is illustrated in Figure 2 (Ames, 2021).

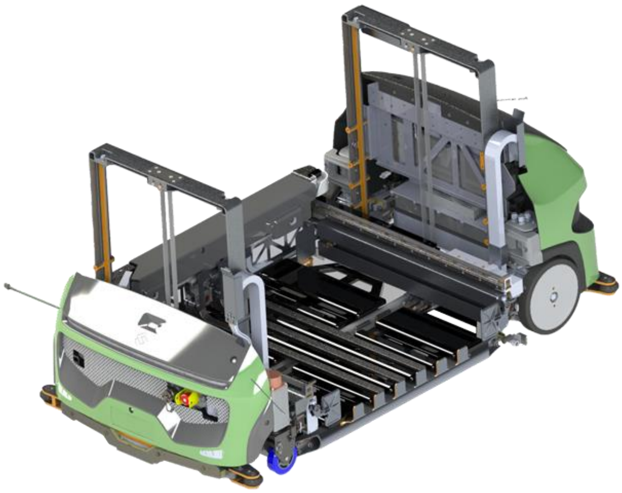

Fig. 2. One of Symbotic's AGV solutions (Ames, 2021)

A third example is SEW's Eurodrive AGV range, which the company is targeting as a logistics assistant for unit load or pallet transport. These AGVs can communicate not only with themselves but also with each other via a WLAN network. Accordingly, route planning is dynamic, adjusting its trajectory based on nearby vehicles.

The AGV group is shown in Figure 3 (SEW Eurodrive, 2022).

Fig. 3. SEW Eurodrive AGV product range (SEW Eurodrive, 2022)

The examples can be continued with Open Shuttle Fork made by KNAPP, which is very flexible and

broadly approved. This device can be seen in the Figure 4 (KNAPP, 2022).

Fig. 4. Open Shuttle Fork (KNAPP, 2022)

We should also address the operational functions of the AGVs: transportation, sortation, sequencing, manipulation, (storage/buffering).

3.2 AMR application examples

The first example is also from the Fraunhofer IML, namely the LoadRunners. This is not an alone device, but a series a similar built devices which can communicate and cooperate with each other. This cooperation can be used in several forms, one of these is illustrated in the Figure 5 (Fraunhofer, 2021).

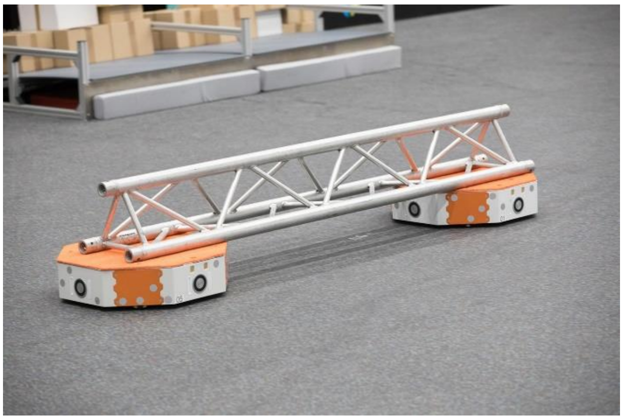

Fig. 5. LoadRunners (Fraunhofer IML, 2021)

The second example is the Filics mobile robot for lifting and moving pallets. This is not a single device that lifts a pallet with a fork, but two separate units that are only virtually in tune with each other. With this type of device, any kind of movement in any direction can be achieved. The navigation is implemented using the SLAM (Simultaneous Location and Mapping) method (AGVnetwork, 2022 & Chen et al., 2017) This device is shown in the Figure 6 (Filics, 2022).

Fig. 6. Filics AMR (Filics, 2022)

Another example of AMR is the system used by Bosch, which is already in use in Hungary. This is the ActiveShuttle, which has the unique feature of being able to express emotions through its display. Navigation is typically done by cameras and built-in distance sensors. This is also a lifting and transportation type. An example of this type is shown in the Figure 7 (Bosch Rexroth, 2022).

Fig. 7. ActiveShuttle (Bosch Rexroth, 2022)

4 A METHOD FOR CHOOSING MATERIAL HANDLING SYSTEMS

To meet customer needs at low cost and/or high service levels, more and more companies are committing to a wide range of digitalization and Industry 4.0 solutions. Various AGV and AMR systems and their combinations are increasingly appearing within the internal logistics systems. It is clear that the operation of these systems is more efficient in certain work cases compared to HR-driven systems, as they are capable of quasi-continuous operation with predictable work cycles, as far as only throughput is concerned. But there is a lack of flexibility and fast scalability, wherein HR-driven systems are "better". There is a growing choice of human operated, AGV and AMR systems on the market, but choosing the right type of material handling system for a given company task is becoming increasingly challenging. The most applicable solution to this task is the simulation of logistics processes. The simulation study allows to model the relevant system variables for a given material handling task and to obtain the basis for comparison, for example, throughput, average cycle time, number of assets required, etc. Furthermore defining and analyzing different scenarios with different probabilities to come up in the future is another core benefit of simulation. The comparison of different material handling systems is usually based on the following aspects:

- Recovery rate: This indicator shows the expected payback time of the material flow system to be developed. Most companies today only support investments with a payback period of less than 3 years.
- Performance (throughput): It shows how much product can be handled by a given material flow system in a unit of time.
- Reliability: Indicates the probability of failure of a given system.
- Availability: This indicator shows what percentage of the available time, if needed, a given material flow system can perform a task.

The reviewed aspects were defined based on our practical experience gained during the design of material flow systems. Of course, these aspects can be supplemented in case of individual needs (e.g., human resource needs, floor area needs, etc.).

The main steps in the proposed selection method are as follows:

1. Define the material handling tasks to be performed: in this step, the tasks to be performed by the material handling system and the requirements for them are defined.

2 Identify the variants of the material handling system: The identification of the variants suitable to perform the tasks defined in step 1 should be carried out in this step. Here the interaction with suppliers starts, also considering nowadays challenges like increased costs and availability.

3. Decision criteria and their importance: In this step, the company defines the decision criteria on which the comparison is based and their importance. In this step, the decision criteria are defined, and the importance of the criteria is determined. Also, a group of stakeholders from different departments should be engaged for the following assessment process (ideally done by a pairwise comparison and a value benefit analysis, not to be subjective). A possible implementation of the application of the selection method was published in one of our previous articles (Szentesi, Sz., Tamás, P., Illés, B., 2018)

4. Simulation

4.1 Design of simulation test model: In this step, the conceptual design of a simulation model for the flow of material and information and the operational concept of a simulation model is defined for the testing of the specified material flow system variations .

4.2 Implementation of the simulation test model: the simulation model will be built using the simulation framework based on the plans defined in the previous section (alternatively, a separate application can be built, but experience shows that this will take much longer than the simulation framework).

4.3 Testing and validation of the simulation model.

4.3 Run and evaluate the results: the simulation test model is run to produce the values of the objective function, which can be used to select the best version for the company. The selection method is a multi-criteria decision method based on normalization and weighting.

5. Assessment and iteration with new parameters or alternative technological solutions,

5 IMPACT OF THE PROPOSED METHOD

In our opinion, companies can realize many advantages by applying the proposed method. On the one hand, these advantages are the reduction of risks in the choice of complex systems by using the simulation test procedure. In addition, by applying the proposed selection method, the most appropriate version of the company's decision criteria system can be selected from a number of alternatives. In our opinion, the proposed procedure can contribute to the reduction of logistical losses (e.g. waiting, unnecessary material handling, etc.), thus increasing the competitiveness of the examined companies.

6 CONCLUDING REMARKS

The publication presents the main characteristics of AGV and AMR systems and identifies the relevant differences between these systems. In addition, the application potential of the different types of systems was demonstrated through practical examples. It was found that the demand for these systems is constantly increasing and that there are many solutions on the market, making it a significant challenge to choose the ideal material handling system for a company. In this context, the concept of a decision method for the selection of a suitable system was developed and presented.

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