Research Article

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The Use of Computer Simulation Methods to Reach Data for Economic Analysis of Automated Logistic Systems

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Abstract: Automated logistic systems are becoming more widely used within enterprise logistics processes. Their main advantage is that they allow increasing the efficiency and reliability of logistics processes. In terms of evaluating their effectiveness, it is necessary to take into account the economic aspect of the entire process. However, many users ignore and underestimate this area, which is not correct. One of the reasons why the economic aspect is overlooked is the fact that obtaining information for such an analysis is not easy. The aim of this paper is to present the possibilities of computer simulation methods for obtaining data for full-scale economic analysis implementation.

Keywords: AGV; simulation; analysis; economics

1 Introduction

The pace of development of logistics is accelerating persistently and businesses need to adjust to that pace. In connection with the changing conditions of production and other processes, logistics are becoming crucial and dynamic field ever more. Businesses must adapt to the growing trend of development that is associated with the increase in production volumes, with extend of the product portfolio and with other aspects. Automated logistics systems are used still at large scale within the intra-plant processes. Automated logistics systems (AGV) are not modern-day matters, their development is dated from the middle of the last century. However, during that time they have undergone enormous development up to the form of modern computerized systems. For these reasons, the AGV issue constitutes one of the dominant themes and direction of current research in the field of logistics. The issue of AGV is wide-spectrum and interdisciplinary. Jaiganesh et al. [1] dealt with issues relating to the guidance and to the operation of the AGV. They focused on the issue of vehicle guidance and determining the position on a transport route and its surroundings. This is a significant and important condition for the effective functioning of logistics system. Operating process of AGV is necessary to continuously monitor and evaluate. This issue was examined in detail by Berman et al. [2] by using simulation tools and statistical analyzes, and resulted in a proposal of decentralized AGVs control method. Another possible principle that can be effectively used for the analysis of the AGVs within the logistic system, is the use of a quantitative method, as Ilić [3] describes. Data obtained from the analysis of the operation of the AGV are a valuable source of information for their design and management. This is connected with questions about the number of vehicles, vehicle routing, solving the collisions and the other problem areas [4, 5]. The issue of path tracking of AGV systems was the object of the research presented in [6]. The authors dealt with AGV navigation systems in industrial environments. This is due to the fact that the AGV systems are used for both the external and the internal transport of materials [7]. Designing the paths can be the key factor for the functioning of AGV systems [8] and operating the AGV system set very high requirements on their management and decision-making system [9–12].

Based on the above, it can be concluded that the necessary condition for the efficient operation of every logistics system with AGV is implementation of their operational analysis. There can be applied a wide range of methods and tools for their implementation. One possibility for effective operational analysis offers the method of computer simulation using software Tecnomatix Plant Simulation.

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2 The characteristics of automated guided vehicle systems

Among automated logistics systems are also ranked AGV (Automated Guided Vehicle = unmanned vehicle). AGV is a comprehensive automation solutions designed for any industry (Fig. 1). The development and implementation of AGV systems help with solving reliable supply for manufacturing lines, they save logistics capacity and allow flexible change of logistic routes. An AGV system uses mechanization for pulling trailers (peripherals) with material according to predefined paths (using magnetic tapes glued to the floor) and with the help of commands (start, speed up, wait, join trailer, unload, etc.), that are stored in the tags (RFID tags) placed along the path.

2.1 The history of automated guided vehicle systems

The history of automated guided vehicle systems started in 1950s (Fig. 2). The American automotive industry was the initiator of the invention of automated guided vehicles and was the first where these systems for organizing modern intralogistics were used. Soon afterwards almost all industries have started to use AGVs to optimize material flows. Automated guided vehicle systems have become a key component of today’s intralogistics. History of AGVs can be divided into four eras according to the state of the technology available. The first era of AGVs began in 1955 and lasted nearly 20 years. At the beginning there had been the idea of replacing the driver of a vehicle for transporting goods using automation. The second era started around 1970 and was characterized by simple experiments with the implementation of the first on-board computers. The third era began in the mid-1990s. The devices were equipped with an electronic guidance systems and proximity sensors. The first attempts using Wi-Fi communication to transfer data were realized. The fourth era is a fluent continuation of the development of the third era. The effort is to go the way of autonomy of these systems up to the level which allows the available technology when the control systems are able to decide autonomously on the motion in space, they are able to detect an obstacle and select an alternate path [13].

2.2 Present of automated guided vehicle systems

It can be said that AGVs is a powerful and necessary tool for modern intralogistics in all branches of industry, by automotive industry, electro technical industry including the pharmaceutical and food industry. Nowadays AGV systems are used the most in the automotive industry. Their main role is to ensure the regular supply of materials and components for continuous flow production process. The AGVs supply the assembly workstations and support the intra-plant and inter-object transportation for assembly knots. Just as the automotive industry is the industry that sets the pace of the economy, as well the most methods of material flow control has its origins in the methods implemented in the automotive industry. AGV is a system that consists of four basic elements:

- guide path,
- guidance system,
- trailers,
- charger unit.
Figure 3: Example of a simulation model to analyze the operation of the AGVs.

The guide path is simply defined according to the required material flow. Movement of the AGV system after the guide path provides the guidance system. The guidance system ensures the smooth flow of trailers with material. For the proper vehicle movement on the route are used various types of automated navigation systems that ensure the vehicles reach the desired destination. Methods of navigation for automated navigation systems are induction, laser and magnetic field [14–17]. However, there are also AGV systems where the navigation is provided by the operator.

There is currently a great demand for AGV from businesses. At the same time there are also many manufacturers on the market who offer these systems. In the Czech Republic the automated logistics systems have the long tradition, they are used for example in ŠKODA Auto. Among the companies, which offer AGV systems in the Czech market include Linde, CEIT, Trilogiq, Still and others.

3 Possibilities of analysis of the automated logistics system operation

The analysis of the automated logistics system operation is an essential prerequisite for their efficient and reliable use within individual processes. Analysis implementation can be done from several aspects. One of the most important is the economic aspect. For implementing this type of analysis is necessary to have a wide range of information and one of the sources for the information except of the data from the real operation is the use of simulation tools (Fig. 3).

When creating a simulation model, in which it is operated AGV system, it is necessary above all to have the idea of the parameters to be monitored and that there is a need to adapt the overall concept of the model. The modeling concept should be designed in the way to approach reality as far as possible. Applying this requirement is often the biggest problem because the available modeling tools are insufficient. In this case, it is often possible to use vari-
Figure 4: Examples of additional programming application in a simulation model.

Figure 5: Example of the information available from the used blocks.

ous supplementary methods, e.g. using the additional programming (Fig. 4).

Thus, formed simulation model provides many opportunities for getting the information. First of all, it is the information obtained directly from the individual blocks representing individual operations and activities within the process analyzed (Fig. 5).

However, the basic range of information offered is often not sufficient for analysis. In this case, it is possible to use separate visualization tools, that can be modified and programmed according to specific requirements. This obtained information can be presented in the form of different graphs (Fig. 6) or tables. In addition to the information portfolio extension, this also helps achieve improved and more attractive presentation of the particular desired parameters.

4 Possibilities of economic analysis of the automated logistics system operation

The economic analysis is an integral part of effective management of business processes. It provides information
from a comprehensive view of the entire enterprise and also about its individual components, activities or organizational units. It allows analyzing logistics of purchasing, sales, production, storage, etc. It is also possible to use the analysis to assess the most of enterprise systems such as an information system or transport system. AGVs are part of the transport system, but to a significant extent they are depend on the information system, which gives them information about when, where and what to deliver.

The analysis of automated logistics system operation provides information on the following areas: maintenance scheduling, operating costs, production planning, information gathering, systems design, process efficiency etc. The data obtained can be used to monitor and reduce operating costs, increase operational reliability, further development of complete systems and options for expanding their deployment in other parts logistics systems.

The evaluation of operation economy must not be simplified only in terms of operating costs. It is necessary to take into account the investment costs and comprehensively evaluate the proportional change of fixed and variable costs arising from the use of AGVs in operation. Within the functioning of intralogistics the AGVs help to reduce the risk of operating leverage. During the AGV evaluation the wide spectrum of information sources play an important role, among which we classify also simulation models.

The information that can be obtained from simulation model about the use of individual transport means is their capacity utilization, which can be the basis: for planning investments, for increasing efficient use of funds, for the reduction of commitment of funding, for reducing the cost of labor, as well as for reducing variable costs associated with their operations or to extend their utilization. The information obtained about the operation of automated logistics systems can then be further processed in accordance with certain selected areas of corporate management, the logistic costs and others.

4.1 Approaches to economic analysis of AGV systems

For the realization of economic analysis of AGV systems we can select several basic approaches (Fig. 7).

The first type is a comprehensive approach. In this approach, AGV system is analyzed in terms of many economic parameters. There are obtained separate outputs by using selected methods (e.g. a simulation method) and these outputs must be summarized and their mutual relations and interactions must be examined for each parameter. When using a mono thematic approach in the frame-
work of economic analysis we focus only on one parameter perhaps even several parameters that are monitored in connection with AGV. It may be, for example, costs associated with charging batteries or capacity utilization of each trailer. Monothematic approach is usually performed based on the results of the preliminary analysis or it can be carried out as a continuation of the comprehensive approach in order to gain more detailed information about an economic item. The monothematic approach can be implemented without previous analyzes, and only at the specific request or for the planned purpose. The third possible type of approach to economic analysis of AGV systems is normative approach. It is an approach in which the parameters are compared in relation to the applicable norms and standards. Ultimately, these may be company standards, trade standards or universally accepted standards. This approach maybe implemented in connection with the performance of daily production standard, it means if AGV systems are able to secure all requirements and thereby ensure the fulfillment of the production plan with the given economic indicators. The penultimate possible approach that can be used for AGV systems analysis is a systematic approach. In this approach, the AGV is understood as a comprehensive system whose operation is influenced by other business systems like supply system, production system, distribution system etc. This means that changes in the production system will affect the AGVs in terms of increasing or reducing transportation requirements and conversely lower transmission capacity of AGVs system has an influence on the size of production capacity. There are mutual ties of the AGV system and the other enterprise systems. The last type of approach to economic analysis of AGV systems is the descriptive approach. It can be used to characterize and describe in detail the operation of the AGV system. The aim is to achieve the objective documentation of various economic indicators in a given situation and time. All these approaches are only in exceptional cases used separately and independently. It is for this reason that in the economic analysis implementation the indicators obtained using a single approach can outline possible direction for analyzes using other approaches. The aim of combining different approaches is to achieve the most unbiased and most credible assessment of the economy of AGV systems operation [15].

5 The use of the simulation model for the performance analysis in economic analysis of AGV

Possibilities of use of the simulation model for the performances analysis of AGVs can be presented in the following example of real AGV system. Performance analysis took place during the testing phase of AGV train, when the quantities of shipped components were monitored respectively, finished products, the number of material turnovers, the number of errors in the individual turnovers and the success in transportation was evaluated. Based on these data, the performance indicators and the average performance for this reporting period were set. Performance analysis is the base for establishing and adjusting the functionality of the model.

5.1 Creation procedure of the simulation model

The diagram of the simulation model formation describes the basic frame of the model. The diagram contains the main steps and actions which are modelled in the simulation model with respect to the needs and requirements of economic analysis. The key inputs are material and pallet, which are subjects to manipulation and production itself (Fig. 8).

The starting point is a pallet and material. Material is placed on a pallet in a desired amount and it is transported in the right time to a given station - assembly line, or production line. Before the actual entry of the material to the line, the material is placed within a container from where it is dispensed in the desired amount in the actual man-
Figure 9: Errors in the AGV train rides.

5.2 The error indicator of AGV train rides

This indicator describes the number of turnovers of AGV train carried out during the reporting period. One turnover in this connection means the ride of train towards the final destination, where the supply takes place, and then the ride back to the store. It further describes the errors that were recorded within those turnovers and on the basis of this data are determine the number of turnovers without error – free of disturbances (Fig. 9). This is an important indicator in terms of the economy, affecting the overall operating and production costs. At this early stage of the transport system implementation, the efforts have been made to set up the optimal performance and to verify capacity options. Also the number of tractors in use was verified with the aim to assess investment and their effectiveness, planning of maintenance costs, charging fuel cells and to assess the use of personal capacities.

During the reporting period, the percentage of successful transportations stood at around 55%. In this period, the errors and deficiencies were recorded that occurred during each rides. These errors were mainly simulated system errors, which are ranked among the more serious matters. Within the simulation were also considered less serious deficiencies, for example obstacles placing at the guide path of AGV train caused by inconsequent employees. During the reporting period, the percentage of successful transportations stood at around 55%. In this period, the errors and deficiencies were recorded that occurred during each rides. These errors were mainly simulated system errors, which are ranked among the more serious matters. Within the simulation were also considered less serious deficiencies, for example obstacles placing at the guide path of AGV train caused by inconsequent employees. The other types of errors that were considered within the simulation model are system errors, i.e. unread marks by AGV train, misread magnetic tape, speed adjustment or some path section adjustment where a train drove out from the guide path. All these errors were represented by a time delay.
5.3 The AGV transport performance indicator

Transport performance means the share of the actual volume of transported materials and finished goods between two points within the enterprise and the total volume of materials and finished goods or material that had to be transported between these two points within the enterprise (Fig. 10). The term transported material respectively finished products from the production is supposed the number of trailers that are loaded with these amounts. This is an indicator that affects the economics of production.

Since it was a testing of AGV transport performance only average performance was achieved. Transport performance during observing reached a level of 55%. Simulation experiments were carried out at the interface of two shifts, namely – morning shift that took from 6 a.m. to 2 p.m. and afternoon shift that took from 2 p.m. to 10 p.m. Attention was focused also on the assessment of the quantity of transported pallets with components on the basis of which could be determine the performance and opportunity for expanding the use and for supply in other parts of the plant.

5.4 The indicator of utilization of AGV rides

This indicator is expressed by the ratio of the number of turnovers of AGV trains and the quantity of transported pallets placed on the trailers operated by AGV train. This is the amount of goods transported on trailers during one turnover expressed as a percentage. The value of indicator is between 100% for a loaded train in both directions and 50% for a loaded train only in one direction either from store or conversely from manufacture to a warehouse (Fig. 11). The drawback is that the train can pull only one transport trailer with material. It is for the reason that the transport trailers with material do not precisely follow the trajectory of AGV trains and thus they interfere with e.g. walking paths. This means that could lead to unwanted contact with staff or other objects, or even with the lines placed along the path.

Within the simulation model were observed transported material amounts and the possibility of the full capacity utilization of the AGV, whose maximum carrying capacity is 1400 kg. While testing, the condition was determined in the simulation model, that one train pulls only one trailer in one direction in order to test passing turns, possibilities of turning and avoiding obstacles. In the model this fact was implemented by the method of additional programming and with the sensors placed on the transport route. The maximal possible number of transport trailers on one journey is three. When analyzing work-load utilization of AGV trains it was found that not every ride of AGV was utilized in one turnover at 100%. The average value of utilization was 63% and it happened for the reason that trailers with finished goods have accumulated at the lines after the night shift. In these cases, the AGV had to complete one journey no-load, because it was not necessary to supply the line with components for manufacturing, the only needed was to carry products back to
the store because they have accumulated in an area that has been assigned for finished goods and they blocked any movement and handling.

5.5 The indicator of time utilization of AGV train

Time utilization is the utilization rate of AGV train in time. The indicator is calculated as share of the total driving time of AGV train at the daily operation time (Fig. 12).

Time utilization of AGV was determined as the ratio of AGV operating time and the total time of daily operation. AGV has been tested every working day from 8 a.m. to 4 p.m. This indicator was determined from performance analysis. The average value of time utilization during the reporting period was 8%. Since the operation runs on four shifts, the actual utilization of AGVs in operation would be only 2%.

5.6 Possibilities of using obtained information

On the basis of the results from the simulation experiments it was found that with the maximum utilization value, i.e. 15 pallets transported for eight hours – the monitored daily operating time is at the turn of morning shift and afternoon shift – the maximal possible transportation is about 30 trailers with components and finished products. This consideration is only theoretical and is based on the observed values of transportations using simulation models. The accuracy depends mainly on the production plan and on the quantity of goods produced during each shift. If it was considered with this ideal condition (30 trailers for 4
shifts), transport capacity in the number of trailers would increase, but the time utilization would remain constant at approximately 8% of the total operating time – 4 shifts after 8 hours (Fig. 13).

On the basis of realized simulation experiments it can be concluded that in terms of time utilization, which can be seen as a key indicator, the use of AGVs is below average. Figure 13 shows that the AGV train is utilized only at a level 7.4% of the total operation time. The transformation to the real time value gives a value that is approximately 2.4 hours from 32 hours representing four operation shifts. Therefore, it would be necessary to extend its scope to other parts, or areas of the plant. The main function of AGV train would be to reduce particular activities currently occupied by operators and stock-keepers.

6 Conclusion

The automated logistics systems are becoming more widely used in the framework of enterprise logistics processes. Their effective management is not possible without a broad spectrum of information resources for the possibility of their economic analysis. Obtaining information for the economic analysis is not easy, for this reason simulation software seems to be a possible solution that will work with the various economic indicators or factors for their determination. When implementing software simulations, it is necessary to take into account a number of factors. First of all is the aspect of time, whether we realize simulation ex-post and ex-ante. Another factor is the purpose of the analysis. The purpose can be determined in the context of increasing manufacturing output, changing the supply system, implementation of new technologies and others.

To create a valid simulation model, it is necessary not only to have a sufficient knowledge of the work with simulation tools, as well as to dispose the high-quality input sources as a result of using the simulation model, which are transformed into outputs in the form of various economic indicators. With such a procedure the operator of AGV systems can obtain a comprehensive overview of the economics of their operations and also can identify reserves and on this basis can evaluate the benefits that the system brings.

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