Ivan ANTONIUK[1], Martin KRAJČOVIČ[2], Radovan SVITEK[3],
Olha KOLESNYK[4], Ľuboslav DULINA[5]

PROJEKTOWANIE ZAUTOMATYZOWANEGO SYSTEMU LOGISTYCZNEGO W ŚRODOWISKU CYFROWEJ FABRYKI

Streszczenie: W dobie przemyslu 4.0 tradycyjne metody projektowania przedsiębiorstw są zastępowane przez narzędzia cyfrowej fabryki. Dlatego w niniejszym artykule opisano nowe podejście do projektowania automatycznych systemów logistycznych w środowisku wirtualnym oraz weryfikację zaprojektowanych rozwiązań za pomocą symulacji dynamicznej. Cały proces jest opisany na przykładzie prawdziwego projektu od fazy początkowej do oceny rozwiązania.

Słowa kluczowe: zautomatyzowany system logistyczny, cyfrowa fabryka, logistyka przemysłowa

DESIGN OF AUTOMATED LOGISTICS SYSTEM IN A DIGITAL FACTORY AREA

Summary: In the age of Industry 4.0, traditional approaches to designing are being replaced using digital factory tools. Therefore, this article describes a new approach to the design of automated logistics systems in a virtual area and verification of designed solutions through dynamic simulation. The whole process is described in the example of a real project from the initial phase to the evaluation of the solution.

Keywords: automated logistics system, digital factory, industrial logistics

1. Introduction to industrial logistics

Logistics is understood as an important process in the establishment, which has to go through the whole establishment and has functions of managing, controlling,

[1] Ing., University of Žilina, Faculty of Mechanical Engineering, Department of Industial Engineering, e-mail: ivan.antoniuk@fstroj.uniza.sk
[2] doc., Ing., PhD., University of Žilina, Faculty of Mechanical Engineering, Deparment of Industrial Engineering, e-mail: martin.krajcovic@fstroj.uniza.sk
[3] Ing., University of Žilina, Faculty of Mechanical Engineering, Department of Industial Engineering, e-mail: radovan.svitek@fstroj.uniza.sk
[4] Ing., University of Žilina, Faculty of Mechanical Engineering, Department of Industial Engineering, e-mail: olha.kolesnyk@fstroj.uniza.sk
[5] doc., Ing., PhD., University of Žilina, Faculty of Mechanical Engineering, Deparment of Industrial Engineering, e-mail: luboslav.dulina@fstroj.uniza.sk

modifying and integrating material flows and intangible information flows, as well as related process such as transportation, storage, material handling and packing. Logistics should be perceived as a closed chain – planning, implementation, inspection and a feedback, afterwards. Logistic costs are significant and often, they are 20 % of the total amount of expanses in manufactural enterprise. In the demands of the high competition market, there is an urgent need of improving processes to reduce costs and prices of products as well. For that reason, the automation and optimization of logistic activities have a high potential and significantly affects other aspects of factory. [1]

1.1. Basic algorithm of logistic systems design

The necessary impulse for starting a design process, is to identify the needs, the origin and the definition of the problem. Then, by analysing the current state of information, knowledge, generating and plan improvement, their application and evaluation. The whole process is cyclical - until the optimum, resp. acceptable plan is created. [2]

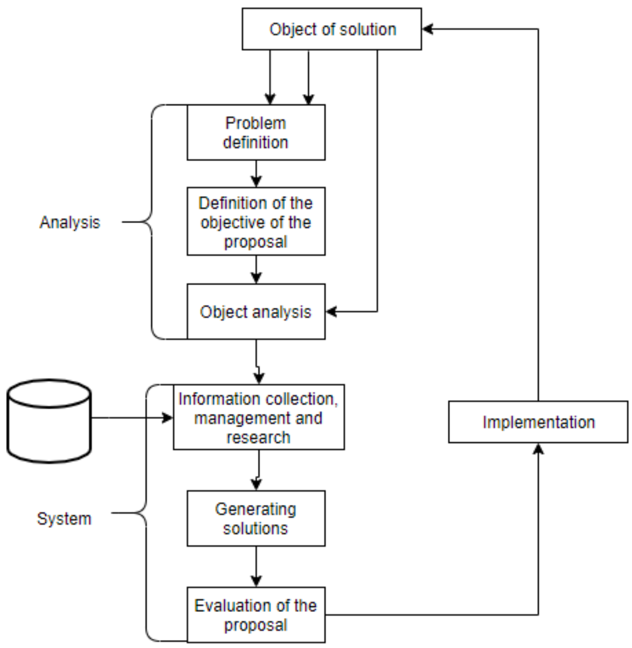

Figure 1. Basic algorithm of logistic systems design [2]

While designing logistics systems, basic paradigms are applicable: model /simulation/heuristic approach, case studies and re-engineering. The most important part in the model approach is gathering, knowledge selection, research and variant generation. In the case study, this phase is a bit easier – finding similar problems, solved from the previous designs, selecting and applying the most suitable variant. In simulation, the generating and evaluating design is based on a functional model. Heuristic approaches are based on the use of man-made solution methods and management, according to the rules and constrains for the individual design. [2, 5]

1.2. Digital factory

A digital factory is a term used to describe a virtual image of real production. It serves for planning, analysis, simulation and optimization of production and logistics systems. Designing in a digital factory environment has many advantages: faster design process, validation of designed solutions through dynamic simulation, vulnerability and collision detection before the project is implemented. [3, 7]

1.3. Unmanaged Logistics System

The automated guided vehicle (AGV) is an unmanned automatic logistics supply system. It is not only a transfer of material from point A to point B according to a predefined path. Moreover, that is complex system consisting of tractors, reloading stations, or dynamic conveyors, which can deliver material on time, automatically unloading it to a designated location. The monitoring software can process production data, react flexibly to it and make independent decisions. It is an automated internal logistics solution that can be effectively used in any industry. Similar systems significantly increase productivity and automation in production, increase weighing accuracy and reduce costs. [1, 4]

2. Procedure of designing a logistics system

Designing a logistics system is a complex process that consists of several phases. At the beginning it is necessary to identify the problem and define the required outputs from the project, to form a research team and to distribute tasks among the members. This is followed by:

- Analysis of the initial state.
- Data collection.
- Processing into the desired form.
- Creation of a simulation model.
- Synthesis of design variants and their verification by dynamic simulation.

The last phase of the project is an economic evaluation of the proposed solutions and selection of a suitable variant for implementation. [1, 6]

2.1. Initial phase of the project

Project identification is the first phase in the design of a logistics system, the task of which is to get acquainted with the company, find out the intention of the company, define the problem and strategy of its solution, and also form a solution team. At the beginning of the project it is very important to precisely define the intention of the company management and its strategy for the future. Then, at the proposal itself, it is necessary to identify the problem and how to solve it with regard to the company's strategy, so that in the future there will be no disagreements between the members of the research team and the chosen solution will not create obstacles in other aspects of the business.

It is necessary to divide the project into individual phases and elements of the solution and assign a responsible person to each element based on the set deadline and the deadline by which the task is to be fulfilled. Following a schedule will ensure a smooth solution to the problem and the achievement of the main objectives within the set deadlines. Splitting the objectives into multiple operational objectives and gradually adopting them at subsequent meetings will help eliminate possible mistakes, improve deadlines and encourage the creation of new ideas.

2.2. System analysis

The analysis of selected production and logistics processes in the plant serves as a basis for the design of the logistics system. Analysis of the current situation should be done in three basic phases: collection of input data and their processing, process analysis itself, summarizing the results of the analysis. The production data collected needs to be verified - it often happens that data from enterprise software is not identical to real production.

Important data to finding:

- Material flow from entrance warehouse, through production to shipping warehouse.
- Characteristics of transport and handling aisles.
- Supplies analysis.
- Data about products, components, places of storage and consumption.
- Environment suitability for implementation of selected AGV system.

2.3. Data processing into a structured database

The Plan for every part (PFEP) database is an ideal form of data processing. An illustration of PFEP is displayed on Figure 2.

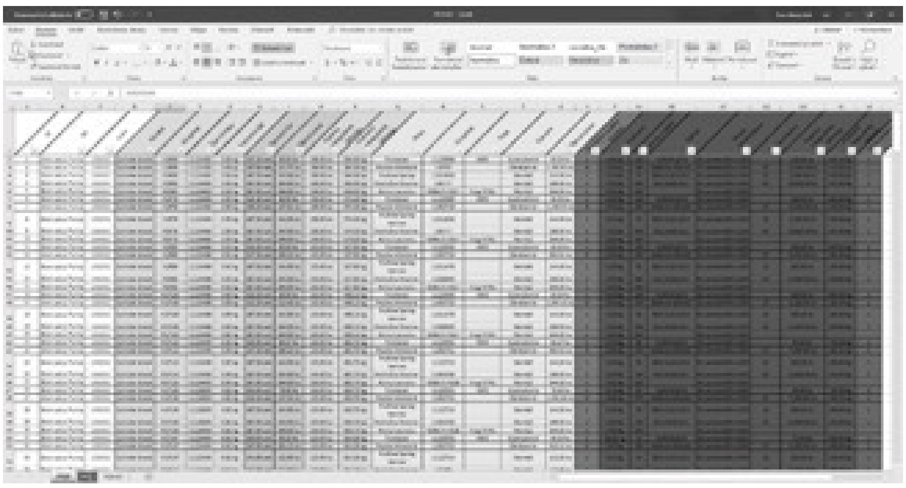

Figure 2. Structured database Plan for Every Part (PFEP) visualisation. [Authors]

All production data are actually available at different departments of factory, that can be compiled into a single structured table, which contains products data, their parts lists, storage locations and component consumption points, quantity information, parts shipping methods, packaging regulations, production outputs and so on. [1] Items can be sorted based on each data. Sorted data can be inserted directly into the computer simulation, which is a great advantage over manual data entry.

2.4. Design of the input/output locations for material.

Production layout of selected workplaces was modelled on the basis of data from 3D laser scanning. Using virtual reality was verified the correctness of all proposed manipulation sites and especially collision control of the location of static C-frames, which are part of the AGV system.

2.5. Creation of simulation model.

Based on the analysis of logistics processes, a supply system for selected workplaces was designed. The aim of the circuit is to transport the semi-finished products from the central warehouse to the production islands according to the production order, to transport the finished products for dispatch and to transport the trolleys and empty pallets back to the central warehouse. [4]
The next step is to create a simulation model in the Tecnomatix Plant Simulation environment for the proposed logistics circuits and selected workplaces. As a basis for model creation was used 2D layout of the plant. As a basis for model creation was used 2D layout of the plant.

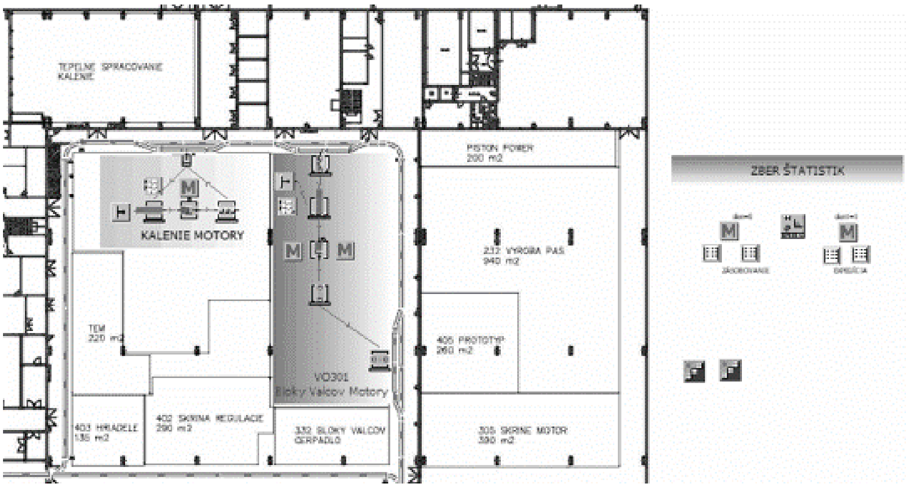

Figure 3. Created simulation model [Authors]

After creating the simulation model, it is necessary to validate and verify it, which means to verify that all processes are running as they are in real system. If the virtual model and the real system are not identical, it is necessary to make some changes respectively. fix possible errors so that the processes in the simulation model accurately represent real production. After these activities, it is possible to continue, apply the proposals and take corrective actions, make simulation experiments.

2.6. Variants designing

When the simulation model corresponds to the real system, it is possible to create design variants and do simulation experiments. Three design variants (table 1) were made under the heading, and two evaluation criteria were defined to select the optimal one: truck capacity and the system's ability to replenish its inventory continuously. The AGV set consists of an AGV truck 3000 A and two dynamic C-frames, with a maximum weight of 3000 kg. The material pallet is stored on the trolleys and, together with this chassis, it will be automatically unloaded from a dynamic C-frame to a static C-frame or vice versa. The trolleys have wheels that allow manual handling but is mainly used as part of an automatic logistics system. [1]

2.7. Variant 1

It is a basic variant with standard loading and unloading times. The system consists of one AGV kit, which consists of one CEIT truck type 3000 A and two automatic dynamic C-frames 1600 x 1000. In this variant, a standard charging logic is applied according to which the truck is charged on each circuit approximately 20 % from the time of ride.

2.8. Variant 2

This design variant is similar in structure to the first design but has different loading and unloading times. It also has a modified charging logic. Due to the fact that the plant logistics works on the 5-shift operation, unlike the production, which is set to the 20-shift, the use of AGV should be as high as possible. The AGV system can operate without charging max. 16 hours, therefore charging during each circuit is cancelled and the tractor will only charge in the afternoon and night shift, so through the shift logistics truck will be constantly in motion.

2.9. Variant 3

Supply through two AGVs. Charging logic is standard – 20 % of travel time during each flight. Loading and unloading times are shortened.

Table 1. Characteristics of design variants [Authors]

Parameters	Design variants		
	Variant 1	Variant 2	Variant 3
Number of the trucks	1	1	2
Charging	2.5 min. every circuit	On the end of the shift	2.5 min. every circuit
Loading/unloading time [s]	105	45	45

2.10. Comparing designs and choosing an optimum

Based on the results of the simulation, it was found that Variánt1 does not meet the requirements of the logistics system and therefore is not suitable for implementation.

Variant 2 and Variant 3 meets the requirements of a given logistics system, with variant three having a low percentage of use of the two trucks. Therefore, Variant 2 with reduced load / unload times and an altered charging system has been approved for implementation.

3. Economic evaluation of the proposed solution

Implementation of the proposed option 2 causes costs: purchase of AGV trucks, peripherals, charging stations, navigation system and information system. After simple calculations of transport performance, it was found that in one-shift operation AGV system saves about 50 % of logistics worker's working time, which can then be used for other productive activities. The cost per logistics employee per year is EUR 24,000. Investment costs are EUR 133,404 and annual savings due to investment are EUR 12,000 per year. The expected return on investment for system expansion is shown in the Table 2.

Table 2 Expected returm of investment [Authors]

System specification	Cumulated investment costs [€]	Number of workers replaced	Annual cost per worker [€]	Return of investment [years]
Variant 2	133,404.0	0.5	24,000.0	11.12
V2 with utilisation of AGV at 100 %	133,404.0	1.0	24,000.0	5.56
2 AGV kits	224,515.0	2.0	24,000.0	4.68
3 AGV kits	315,626.0	3.0	24,000.0	4.38
4 AGV kits	406,737.0	4.0	24,000.0	4.24
5 AGV kits	497,848.0	5.0	24,000.0	4.15

The vision of a selected logistics company in the future is to fully automate the production supply process. Adding additional AGV kits to the existing system will result in lower investment costs and better return of investment.

4. Conclusion

The main aim of this work was to describe the process of designing an automated logistics system using AGV trucks on a project from a selected company. Designing in a digital factory environment allows you to select the optimal variant of a logistics system by validating through dynamic simulation. By using reverse engineering - 3D laser scanning and modelling, it is possible to verify the placement of elements in the workplace, such as the location of logistics elements on the production workplace line. The described procedure can be used as a practical aid in designing of a similar system.

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REFFERENCES

1. ANTONIUK, I. Návrh automatizovaného logistického systému: diplomová práca. Žilinská univerzita v Žiline, 2019. 77 s.
2. MALINDŽÁK, D., TAKALA, J.: Projektovanie logistických systémov (teória a prax). Košice : EXPRES PUBLIC s.r.o., 2005. 226 s. ISBN 88-8073-282-5.
3. GREGOR, M.: Digitálný podnik. Žilina : Slovenské centrum produktívity : s.n., 2006 a. ISBN 80-969391-5-7.
4. BUBENÍK P., KADUCH P.: Vzdelávanie modelovacích techník prostredníctvom e-learningu In: InvEnt 2006 [elektronický zdroj]: moderné trendy v oblasti priemyselného inžinierstva: medzinárodná konferencia doktorandov, Strečno, 18.-19.5.2006: zborník referátov. - V Žiline: Žilinská univerzita, 2006. - ISBN 80-969391-1-4. - S. 160-165. - Požiadavky na systém: Windows 95 a vyššie; CD-ROM mechanika.
5. BARBUŠOVÁ M., BIGOŠOVÁ E., ČECHOVÁ I..: Systém merania productivity v podniku. In: Projekt interdyscyplinarny projektem XXI wieku. Monografia. Bielsko-Biała. Wydawnictwo Akademii Techniczno-Humanistycznej. 2018. ISBN 978-83-65182-92-0.
6. SKOKAN R., BUČKOVÁ M. 2017: Application of logistics FMEA in the selected enterprise. In: Projekt interdyscyplinarny projektem XXI wieku. Monografia. Bielsko-Biała: Wydawnictwo Akademii Techniczno-Humanistycznej. 497-504p. ISBN 978-83-65192-80-7.
7. FURMANN, R. 2007. Návrh algoritmu pre tvorbu výrobných dispozícií vo virtuálnom prostredí. Žilina: Žilinská univerzita v Žiline, katedra priemyselného inžinierstva. Dizertačná práca, 2007.