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Computer aided design of logistics systems

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INTRODUCTION

Current markets and customers require that manufacturing systems designers apply new, advanced approaches and tools in designing future manufacturing systems. The Digital Factory concept seems to be one of the most appropriate approaches to fulfil this task, offering all required functions, among others: a central database, digital models, integrated data management, modelling and simulation functions, visualisation through virtual reality (Gregor and Medvecký, 2010). Virtual reality has become a common tool used in the Digital Factory environment, which creates the environment for innovation of products, processes and resources (Gregor et al., 2007).

Today, competitive global markets require high quality, quick production and low cost. Such market requirements create the need for collaboration of all professions, from engineers and managers to shop-floor workers, and the need to share knowledge and experience with the use of new information technologies.

The evolution of production systems follows the development of innovative technology and its direct environment, like machines, devices, methods and tools aiding the work related to preparing technical documentation, including description of product models, processes and production resources. This can be achieved by introducing shorter production cycles, new products and manufacturing processes development, more efficient logistics, and using more effective and innovative ideas, like Lean Production, Total Quality Management, and digital technologies (Lewandowski et al., 2014).

Organization of the logistic chain is strictly connected with computer technology which is used in the enterprise. The complex computer systems in enterprises, which are being developed currently, are ERP class systems (Enterprise Resource Planning), defined as sets of integrated software packages which can offer coherent information

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flow in an enterprise. In the area of production, we can mention CAD, PDM, CAM, DNC systems, which are integrated with them (Bagheri at al., 2015). The next kind of systems which are being developed nowadays, are the systems of Supply Chain Management (SCM) and of Customer Relationship Management (CRM). These systems integrate the activities among business partners on the strategic, tactic, and operational levels and function in integrated chains within the frames of one enterprise on the account of lack of adaptation to changes in the chains consisting of independent partners.

LOGISTICS – RESEARCH METHODOLOGY

In modern industrial practice, innovative solutions are constantly being proposed to improve processes or entire production or logistics systems (Gregor et al., 2018). In order to implement new technologies, companies must be able to combine the use of the latest and available technologies. It is essential for businesses to be aware of current developments (Kolberg and Zühlke, 2015).

Logistics is still the main factor of success in industrial organizations on the global market. The current effort of modern logistics system designers is the ability to adapt for quickly changing market conditions (customer requirements). It is necessary to change quickly the structure and organization of production, and it is often time consuming and expensive (Dulina and Bartanusova, 2014).

Nowadays, production processes managers are primarily focused on improving the efficiency of internal processes. They want to manage these processes intelligently and to reduce costs and labour consumption. Therefore, production plants need a realistic visualisation of their present state, risks and opportunities to manage improvements effectively. It will be possible thanks to implementing new technologies and transforming the existing factories through digitization (Bučková et al., 2017).

In the example described below, there CEIT Table system was used (CEIT Table, 2019). It is a tool for designing production and logistics systems in a 3D environment. This system includes features and modules, which help to design production layouts and logistics processes using 2D / 3D models. After entering the input parameters, the system evaluates them interactively with respect to the state and nature of the projected production layout. After making any change, the system interactively evaluates the change and calculates parameters of the proposed production and logistics system (Plinta, 2016). For the purposes of designing logistics concepts in the context of Industry 4.0, the system allows to generate logistic links for all types of handling technology (man, tractor, VZV, FTS / AGV), to render them through material, transport flows and capacity, and verify them.

CURRENT PROBLEMS IN LOGISTICS

Ensuring production continuity and quality leads organizations to think about the current state of logistics and manufacturing systems. Management lacks data, information, methods and tools for making decision. The problem is that planning, production management and logistics are based on principles, which have been used for over a hundred years. In the last twenty years, Lean Management and Six Sigma – the main philosophies of production improvement have progressed successfully. However, today it is not enough for production companies. The combination of the mentioned concepts with digitization brings a completely new quality for the decision

making (Miebach and Müller, 2006). This combination should be based on planning, which is conducted by interactive software scheduling systems. This paper describes research in the field of application of the software solutions for logistics systems analysis and planning (Plinta and Krajčovič, 2015).
The presented research was carried out in an automotive company. Current problems, which are connected with logistics systems design in such companies include the following factors:

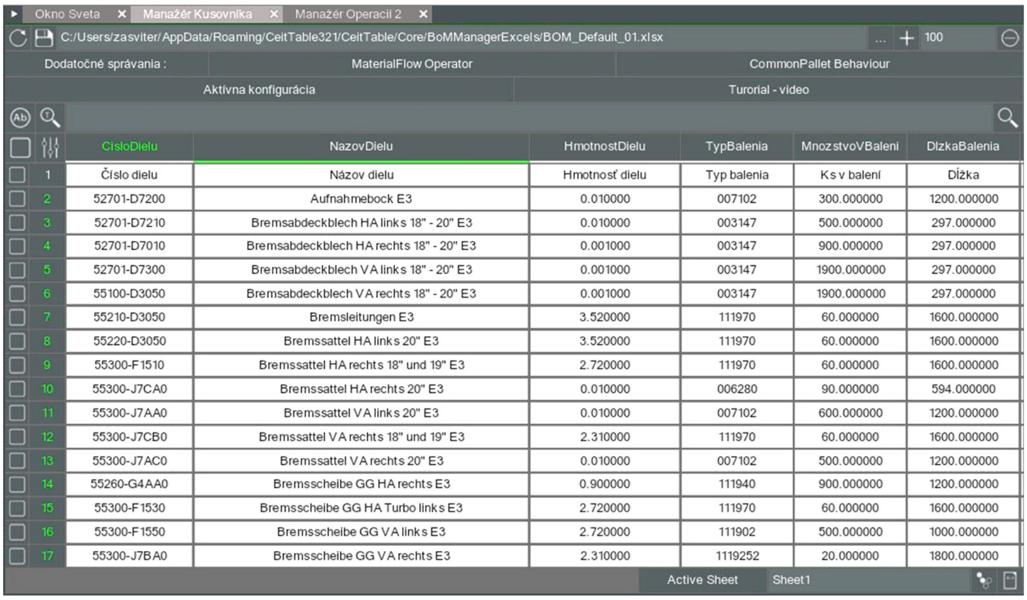
- inaccurate scheduling due to inaccurate or incomplete data.
- missing or inefficient software,
- shortcomings in the information flow,
- human errors, which are caused by insufficient system of work, lack of rules and low motivation,
- oversized or undersized capacities - people, transportation means, production areas, warehouses.
- inappropriate logistics strategy - inflexible warehouses, chaotic storage, outsourcing, insourcing.
- problematic data acquisition, insufficient validity and outdated data.
- inefficient packaging, missing packaging regulations.
- insufficient material flow, etc.

SOLUTION

Nowadays, the known methods of production improvement are complemented with new technologies, which facilitate, for example, collecting information, processing it, realization of analyses, finding the best solution and verifying it. It is an old methodological approach, but with the use of new technological possibilities it gives us a completely different dimension and added value (Mičieta et al., 2014). Analysing a digital copy of a real system is much easier than it would have been in the past. For example, the CEIT-Table system (hardware and software) can be used for such analysis. Designing logistics systems with this system should be realized at the beginning of projects. Basic input data, which is needed for logistics system analysis, can be divided into the following categories:

- the information describing the produced parts: part name and number, part weight, packaging type, number of pieces in a package, length, width, height of packaging, net weight of package and stackability.
- the information describing the production process: the manufacturing process with basic information (operation number, operation name, unit production time, workplace / machine on which the operation will be realized).
- availability of different types of production resources (workplaces, workers): number of working hours per shift, number of available working days per year.
- current logistics plans, staging points, number of staff and number of handling equipment.

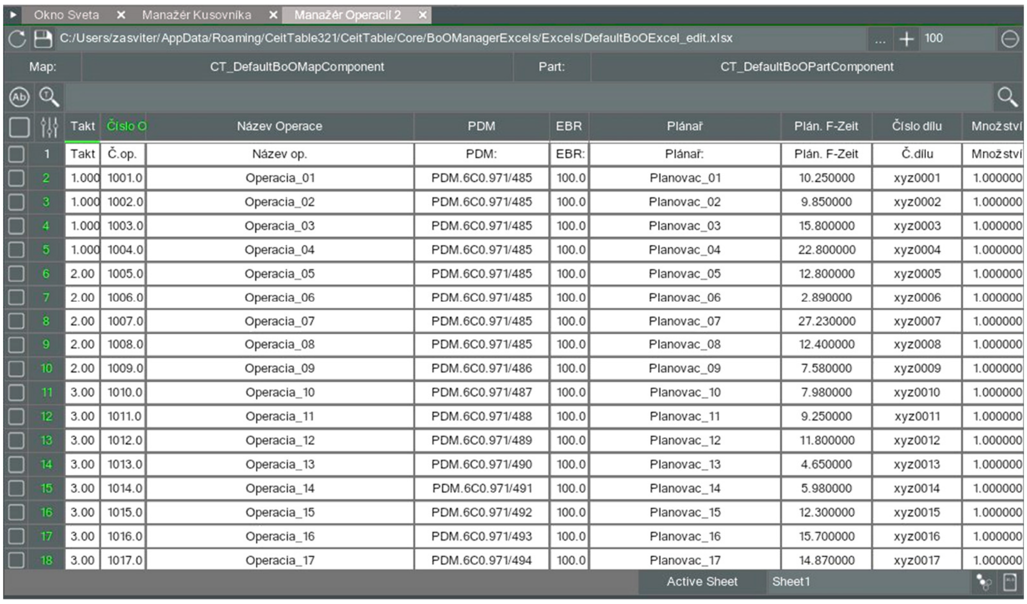
Input materials for production are the source of final products. Only when final products have been sold, their costs will be covered. Therefore, it is very important to move material quickly and directly between the necessary processes to create value. An external data file is created from the collected data, most often in spreadsheets, and imported into the software for production management (Fig. 1). The main data set is BOM (Bill Of Material), which makes easier for the user to directly allocate input materials for processing on workplaces according to the manufacturing process.



	CisloDielu	NazovDielu	HmotnostDielu	TypBalenia	MnozstvoVBaleni	DlzkaBalenia
1	Číslo dielu	Názov dielu	Hmotnosť dielu	Typ balenia	Ks v balení	Dĺžka
2	52701-D7200	Aufnahmebock E3	0.010000	007102	300.000000	1200.000000
3	52701-D7210	Bremsabdeckblech HA links 18" - 20" E3	0.010000	003147	500.000000	297.000000
4	52701-D7010	Bremsabdeckblech HA rechts 18" - 20" E3	0.001000	003147	900.000000	297.000000
5	52701-D7300	Bremsabdeckblech VA links 18" - 20" E3	0.001000	003147	1900.000000	297.000000
6	55100-D3050	Bremsabdeckblech VA rechts 18" - 20" E3	0.001000	003147	1900.000000	297.000000
7	55210-D3050	Bremsleitungen E3	3.520000	111970	60.000000	1600.000000
8	55220-D3050	Bremssattel HA links 20" E3	3.520000	111970	60.000000	1600.000000
9	55300-F1510	Bremssattel HA rechts 18" und 19" E3	2.720000	111970	60.000000	1600.000000
10	55300-J7CA0	Bremssattel HA rechts 20" E3	0.010000	006280	90.000000	594.000000
11	55300-J7AA0	Bremssattel VA links 20" E3	0.010000	007102	600.000000	1200.000000
12	55300-J7CB0	Bremssattel VA rechts 18" und 19" E3	2.310000	111970	60.000000	1600.000000
13	55300-J7AC0	Bremssattel VA rechts 20" E3	0.010000	007102	500.000000	1200.000000
14	55260-G4AA0	Bremsscheibe GG HA rechts E3	0.900000	111940	900.000000	1200.000000
15	55300-F1530	Bremsscheibe GG HA Turbo links E3	2.720000	111970	60.000000	1600.000000
16	55300-F1550	Bremsscheibe GG VA links E3	2.720000	111902	500.000000	1000.000000
17	55300-J7BA0	Bremsscheibe GG VA rechts E3	2.310000	1119252	20.000000	1800.000000

Fig. 1 The created external data source for BOM (Bill Of Material)

The data set, which defines the production processes (Fig. 2), is called BOO (Bill of Operations). These operations are allocated to individual workplaces according to the manufacturing workflow.



	Takt	Číslo O	Název Operace	PDM	EBR	Plánař	Plán. F-Zeit	Číslo dílu	Množství
1	Takt	Č.op.	Název op.	PDM:	EBR:	Plánař:	Plán. F-Zeit	Č.dílu	Množství
2	1.000	1001.0	Operacia_01	PDM.6C0.971/485	100.0	Planovac_01	10.250000	xyz0001	1.000000
3	1.000	1002.0	Operacia_02	PDM.6C0.971/485	100.0	Planovac_02	9.850000	xyz0002	1.000000
4	1.000	1003.0	Operacia_03	PDM.6C0.971/485	100.0	Planovac_03	15.800000	xyz0003	1.000000
5	1.000	1004.0	Operacia_04	PDM.6C0.971/485	100.0	Planovac_04	22.800000	xyz0004	1.000000
6	2.00	1005.0	Operacia_05	PDM.6C0.971/485	100.0	Planovac_05	12.800000	xyz0005	1.000000
7	2.00	1006.0	Operacia_06	PDM.6C0.971/485	100.0	Planovac_06	2.890000	xyz0006	1.000000
8	2.00	1007.0	Operacia_07	PDM.6C0.971/485	100.0	Planovac_07	27.230000	xyz0007	1.000000
9	2.00	1008.0	Operacia_08	PDM.6C0.971/485	100.0	Planovac_08	12.400000	xyz0008	1.000000
10	2.00	1009.0	Operacia_09	PDM.6C0.971/486	100.0	Planovac_09	7.580000	xyz0009	1.000000
11	3.00	1010.0	Operacia_10	PDM.6C0.971/487	100.0	Planovac_10	7.980000	xyz0010	1.000000
12	3.00	1011.0	Operacia_11	PDM.6C0.971/488	100.0	Planovac_11	9.250000	xyz0011	1.000000
13	3.00	1012.0	Operacia_12	PDM.6C0.971/489	100.0	Planovac_12	11.800000	xyz0012	1.000000
14	3.00	1013.0	Operacia_13	PDM.6C0.971/490	100.0	Planovac_13	4.650000	xyz0013	1.000000
15	3.00	1014.0	Operacia_14	PDM.6C0.971/491	100.0	Planovac_14	5.980000	xyz0014	1.000000
16	3.00	1015.0	Operacia_15	PDM.6C0.971/492	100.0	Planovac_15	12.300000	xyz0015	1.000000
17	3.00	1016.0	Operacia_16	PDM.6C0.971/493	100.0	Planovac_16	15.700000	xyz0016	1.000000
18	3.00	1017.0	Operacia_17	PDM.6C0.971/494	100.0	Planovac_17	14.870000	xyz0017	1.000000

Fig. 2 The imported BOO (Bill Of Operations)

Now, typical design of manufacturing and logistics systems is much more flexible and efficient, thanks to the use of modern digital technologies and procedures. During creation of a digital copy of a real production and logistics system, in a software like CEIT Table, a current production layout is drawn and individual 3D objects are inserted into it. The created production layout with 3D objects embedded in the CEIT

Table system is not only for visualization. The machine model in this system is a parametric object, which is composed of several elements (Furmann and Krajčovič, 2011). These elements allow the objects to communicate with each other and allocate operations and parts to them from an external data source, like BOM or BOO.
In most cases, production system modelling is based on the current state. Then, after parameterization of individual objects, the spatial layout is modelled using the imported production layout drawing (Fig. 3). This software, on the basis of the created model, can already provide information about the size of areas in production halls, used and unused areas, visualize the necessary service zone for machines, and so on (Furmann and Furmannová, 2016).

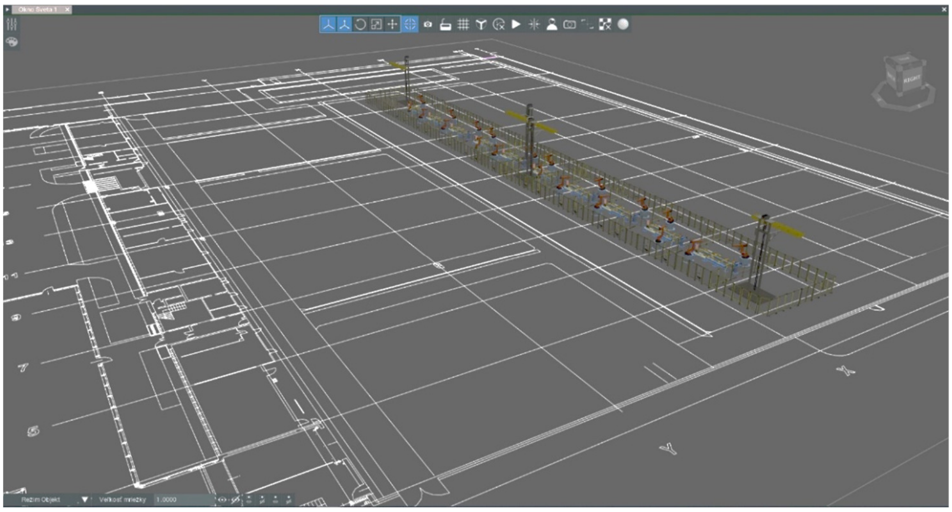


Fig. 3 Creating a digital copy of a real system based on the current state

After designing the production layout, it is necessary to proceed to the logistic supply planning. Modelling of the logistics system in most cases is based on the company's current supply plan.
Thanks to the modelled logistic system, we are able to verify the proposed improvements in the manufacturing system from the point of view of logistic processes. In the software mentioned above, the material flow modelling is conducted using a checkerboard of transport relations (from where to) - Fig. 4. It is a table in which workplaces mentioned in rows are sender workplaces and columns feature target workplaces.

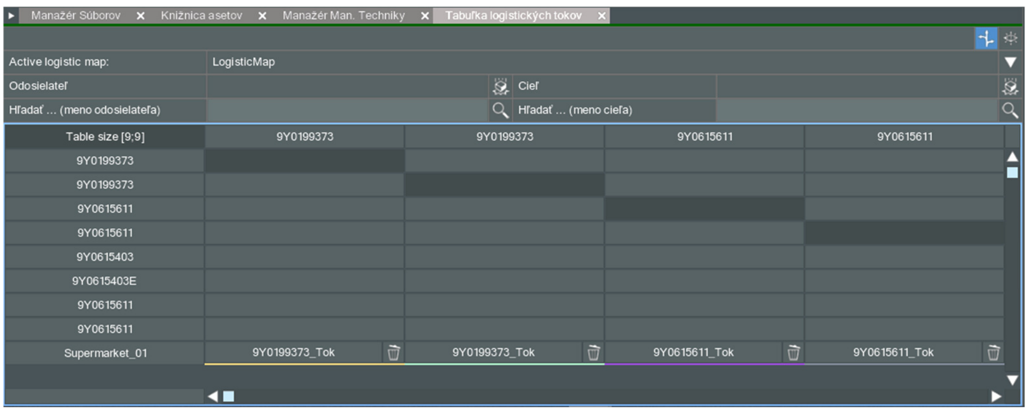


Fig. 4 A checklist of transport relations "from where to"

After creating material flows and supply circuits, it is possible to allocate these flows and circuits to particular transport and handling means. It is important to note that each transport or handling element (object) is parameterized. They are attributed by different parameters, such as: speed, availability, need for charging, maximum transported weight, device flexibility.
After assigning the individual circuits to the transport devices, the software, on the basis of interaction between parametric objects, gathers information about the capacity load and the total travel distance of the handling and transport means (Fig. 5). It is a very good tool for evaluating means of transport used in a logistics system.
The graph in Figure 5, which was created in the CEIT Table software, shows individual utilization of handling and transport means, according to the current logistics supply plan. In more detail, the problem of loading handling means is shown in Table 1. The results of the analysis were also confirmed by the following problems of logistics systems in the analysed company:
– insufficient overview of material flow,
– problematic data acquisition, insufficient validity and outdated data,
– missing or inefficient software,
– incomplete information flow,
– inaccurate scheduling due to inaccurate or incomplete data.
– oversized or undersized capacities - people, transportation means.

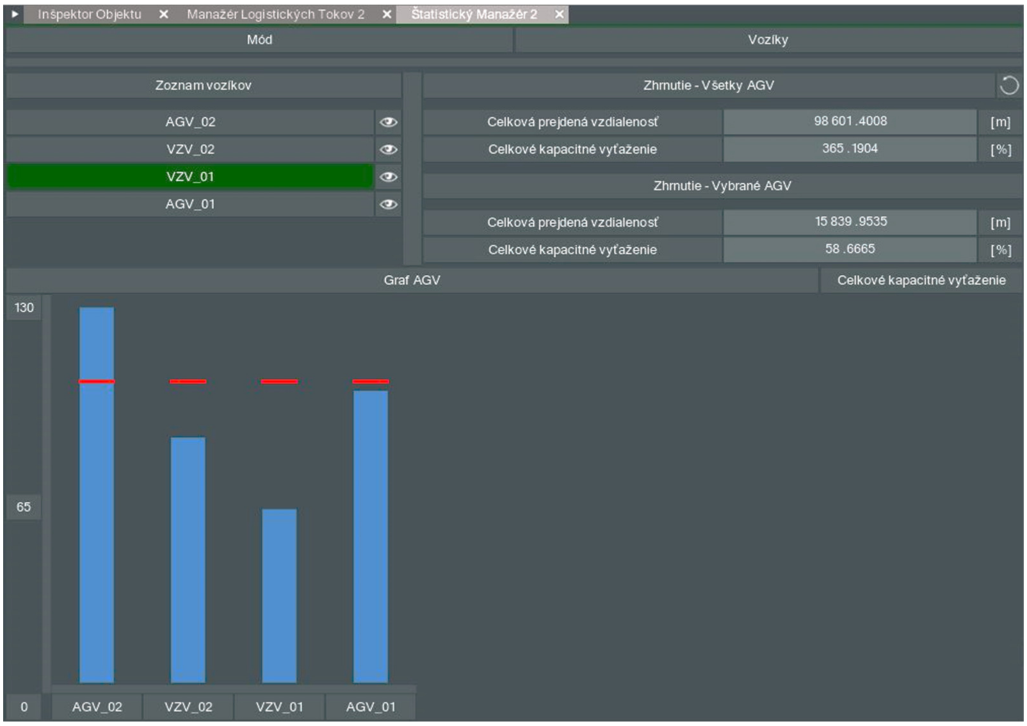


Fig. 5 Capacity evaluation of handling and transport means

Table 1
Utilization of handling and transport means (current system state)

Truck Name	Total distance travelled [m]	Total utilization [%]
AGV_01	26480.62	98.08
AGV_02	34003.95	125.94
VZV_01	15839.95	58.67
VZV_02	22276.88	82.51

The used software includes features and work modules, which help us work and make decisions easier during designing a new logistics system and logistics supply plans. After entering the input parameters, we can evaluate them taking into account the state and nature of the production disposition. With such a tool, we can create several variants of supply plans. After introducing the proposed changes, the system interactively evaluates their impact and recalculates the resulting parameters of the analysed logistics system. The supply system for the analysed production has changed:

– distribution of parts will be equal to individual logistics resources possibilities, according to the calculated consumption rate of parts at workplaces,
– the direction and orientation of individual transport was redesigned, taking into account the most optimal links between workplaces,
– introduction of standards related to types of materials packaging.

Based on the proposed changes, it was possible to design an optimal supply plan for all used logistics resources (Fig. 6). It was possible to see their utilization after implementing changes.

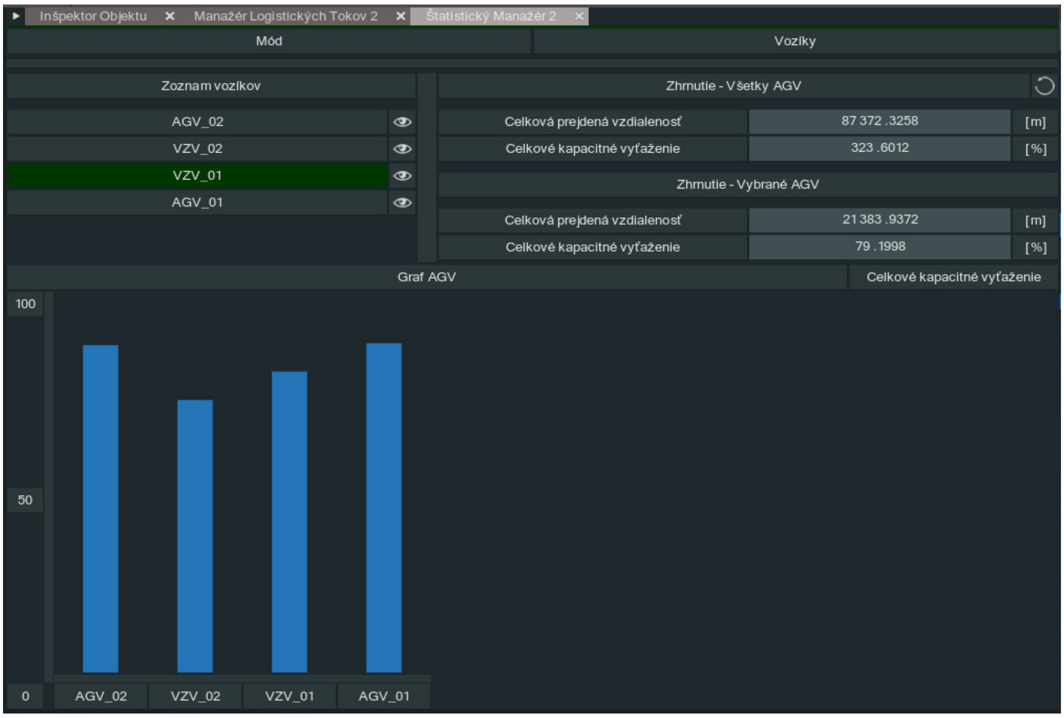


Fig. 6 Capacity evaluation of handling and transport means after the changes

Table 2 shows the utilization of logistics facilities after the changes. The transport of particular parts, based on the analysed frequency of their consumption, to and between workplaces allows us to optimize the realization of supply tasks and more evenly utilize individual resources in the logistics system.

Changing the direction and orientation of particular transport routes in the system allows us to achieve shorter total distance and to find the optimal link between the source and the target consumption for the given parts. The proposed change in wrapping unit types of individual consumed parts also affects the share of the overall travelled distance, which causes a reduction in the weighing frequency.

Table 2
Utilization of handling and transport means (future system state)

Truck Name	Total distance travelled [m]	Total utilization [%]
AGV_01	23365.25	86.54
AGV_02	23256.22	86.13
VZV_01	21383.94	79.20
VZV_02	19366.91	71.73

It is not a problem to create the layout of a new production hall today, but debugging the processes in a real production system is not only laborious, but, above all, very expensive. Additionally, some collisions could remain undetected, causing problems at later stages. However, with the use of a parametric scheduling system, it is possible to identify and eliminate deficiencies during planning. The achieved visualization allows for a better control of logistic processes. Many companies use such tools due to the fact that modern technology and advanced approaches give us the opportunity to make a huge start.

The main way for efficient optimization of material flows in a production system is by proper determination and definition of logistic planning, and the team of experts involved in planning workshops, designing the new or re-designing the old manufacturing systems. Their task is to plan, count, change and then recalculate, continually improving and re-evaluating logistic systems.

Based on the results presented in this paper, we can conclude that such software can be used to for complex logistic analyses.

CONCLUSION

New functionalities of the described kind of software are already necessary in designing and evaluating complex manufacturing and logistics structures. The solutions offered by this software make it possible to define mutual communication and interaction between individual objects. Therefore, it is a very effective tool for designing, thanks to which we can easily change all elements of the modelled system. This means that after changing the chosen element, the software recalculates parameters and relationships between other objects. Such a system reacts flexibly to changes and with its help, it is possible to determine how the changes will affect the system.

Different kinds of contemporary design tools can create a complex system of interconnected and interactive elements, which can provide manufacturing companies with a lot of detailed information. Such a system may be an important source of information on the possibilities and effects of the implemented improvements, therefore it is an excellent tool aiding the decision making process in manufacturing companies.

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Abstract: This paper presents a possibility of applying modelling and simulation in logistic processes management and design in production enterprises. New functionalities of the modelling software, especially those connected with analysing material and information flow, are already necessary for designing and evaluating complex logistic systems. The possibilities of modelling and simulation with the use of the CET Table system are illustrated by practical example.

Keywords: logistic processes, digital factory