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CYFROWA TRANSFORMACJA PROCESÓW LOGISTYCZNYCH W PRZEMYŚLE MOTORYZACYJNYM

Streszczenie: W czasach Przemysłu 4.0, cyfryzacja wszelkich procesów jest powszechnie realizowana, a przedsiębiorstwa przemysłowe przeprowadzają wzmożony proces digializacji poprzez narzędzia fabryki cyfrowej oraz cyfrowego bliźniaka. W tym artykule opisano proces digitalizacji logistyki wewnątrzzakładowej w przemyśle samochodowym. Cały proces opisano krok po kroku – od postawienia celów projektowych do jego ewaluacji za pomocą wybranych narzędzi planowania cyfrowej fabryki.

Słowa kluczowe: cyfrowa fabryka, logistyka wewnątrzzakładowa, tzw. kurs mleczarza, transformacja cyfrowa

DIGITAL TRANSFORMATION OF LOGISTICS PROCESSES IN AUTOMOTIVE INDUSTRY

Summary: In the era of Industry 4.0, the digitization of processes is booming, and industrial companies are increasingly digitizing their processes through digital factory's and digital twin's tools. This article describes the process of digitization of internal logistics processes in the automotive industry. The whole process is described from the setting of project goals to its evaluation in the selected digital factory planning tool.

Keywords: cyfrowa fabryka, logistyka wewnętrzna, przepływ mleka, transformacja cyfrowa

1. Introduction

When designing logistics systems, it is important that a logistics system is designed in the pre-implementation phase in a way, that considers and meets the specified techno-economic parameters. The use of digital factory tools is beneficial in terms of the possibility of verifying the future states of the logistics system with respect to

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the implementation of the proposed optimization options. This verification in a virtual environment saves time and money that would be spent on potential modifications and interventions to the existing system in full operation. Digital factory tools allow the designer to flexibly generate several suitable variants and, given the defined objectives, allow him to select the optimal solution variant [1,2].

This article describes the digital transformation of logistics processes in the automotive industry and is divided into three parts:

- Goal definition of digital transformation of logistics processes and collection of input data.
- Creating the data structure of the parametric model – linking components entering the assembly process to storage locations in the warehouse as well as to the points of consumption on assembly line, creation of material flows, and their assignment to logistics vehicles.
- Evaluation of the current state of logistics processes, identification of bottlenecks, and proposal of measures to make the logistics system more efficient.

2. Case study

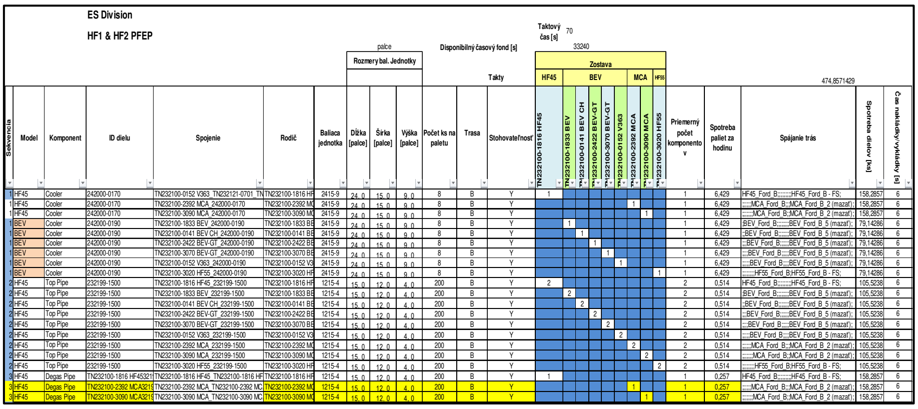
The project aimed to propose a procedure for implementing digital factory and digital twin tools in the logistics processes of a company in the automotive industry, as well as to evaluate the current state of logistics processes based on data collection using RTLS and subsequently optimize these processes.

2.1 Collection of input data for the purpose of creating a parametric model of the logistics system

The basic data required for the creation of a parametric model of logistics system are:

- PFEP (plan for every part).
- Delivery route plans.
- Data on logistics processes and logistics equipment.
- RTLS data.

Plan For Every Part (PFEP) is a database that contains information about each component that enters the manufacturing process under a unique numerical designation. Based on the data contained in the PFEP, it is possible to identify part consumption volumes, stock positions, consumption points, packaging regulations for each part, handling times, and more. These data should be merged in one table as can be seen in (Fig. 1), given that it is often the case that individual data are located in different databases, and therefore they are difficult to trace [3].



ES Division

HF1 & HF2 PFEP

Taktový čas [s] 70

Disponibilný časový fond [s] 33240

palce — Rozmery bal. Jednotky

Takty — Zostava: HF45 | BEV | MCA | HF55

474,8571429

Sekvencia	Model	Komponent	ID dielu	Spojenie	Rodič	Baliaca jednotka	Dĺžka [palce]	Šírka [palce]	Výška [palce]	Počet ks na paletu	Trasa	Stohovateľnosť	TN232100-1816 HF45	TN232100-1833 BEV	TN232100-0141 BEV CH	TN232100-2422 BEV-GT	TN232100-3070 BEV-GT	TN232100-0152 V363	TN232100-2392 MCA	TN232100-3090 MCA	TN232100-3020 HF55	Priemerný počet komponentov	Spotreba paliet za hodinu	Spájanie trás	Spotreba dielov [ks]	Čas nakládky/vykládky [s]
1	HF45	Cooler	242000-0170	TN232100-0152 V363_TN232121-0701_TN	TN232100-1816 HF	2415-9	24.0	15.0	9.0	8	B	Y	1									1	6,429	HF45_Ford_B;;;;;;;;;HF45_Ford_B - FS;	158,2857	6
1	HF45	Cooler	242000-0170	TN232100-2392 MCA_242000-0170	TN232100-2392 MC	2415-9	24.0	15.0	9.0	8	B	Y							1			1	6,429	;;;;;;MCA_Ford_B;;;MCA_Ford_B_2 (mazať);	158,2857	6
1	HF45	Cooler	242000-0170	TN232100-3090 MCA_242000-0170	TN232100-3090 MC	2415-9	24.0	15.0	9.0	8	B	Y								1		1	6,429	;;;;;;;MCA_Ford_B;;MCA_Ford_B_2 (mazať);	158,2857	6
1	BEV	Cooler	242000-0190	TN232100-1833 BEV_242000-0190	TN232100-1833 BE	2415-9	24.0	15.0	9.0	8	B	Y		1								1	6,429	;BEV_Ford_B;;;;;;;;BEV_Ford_B_5 (mazať);	79,14286	6
1	BEV	Cooler	242000-0190	TN232100-0141 BEV CH_242000-0190	TN232100-0141 BE	2415-9	24.0	15.0	9.0	8	B	Y			1							1	6,429	;;BEV_Ford_B;;;;;;;BEV_Ford_B_5 (mazať);	79,14286	6
1	BEV	Cooler	242000-0190	TN232100-2422 BEV-GT_242000-0190	TN232100-2422 BE	2415-9	24.0	15.0	9.0	8	B	Y				1						1	6,429	;;;BEV_Ford_B;;;;;;BEV_Ford_B_5 (mazať);	79,14286	6
1	BEV	Cooler	242000-0190	TN232100-3070 BEV-GT_242000-0190	TN232100-3070 BE	2415-9	24.0	15.0	9.0	8	B	Y					1					1	6,429	;;;;BEV_Ford_B;;;;;BEV_Ford_B_5 (mazať);	79,14286	6
1	BEV	Cooler	242000-0190	TN232100-0152 V363_242000-0190	TN232100-0152 V3	2415-9	24.0	15.0	9.0	8	B	Y						1				1	6,429	;;;;;BEV_Ford_B;;;;BEV_Ford_B_5 (mazať);	79,14286	6
1	BEV	Cooler	242000-0190	TN232100-3020 HF55_242000-0190	TN232100-3020 HF	2415-9	24.0	15.0	9.0	8	B	Y									1	1	6,429	;;;;;;;;HF55_Ford_B;HF55_Ford_B - FS;	79,14286	6
2	HF45	Top Pipe	232199-1500	TN232100-1816 HF45_232199-1500	TN232100-1816 HF	1215-4	15.0	12.0	4.0	200	B	Y	2									2	0,514	HF45_Ford_B;;;;;;;;;HF45_Ford_B - FS;	105,5238	6
2	HF45	Top Pipe	232199-1500	TN232100-1833 BEV_232199-1500	TN232100-1833 BE	1215-4	15.0	12.0	4.0	200	B	Y		2								2	0,514	;BEV_Ford_B;;;;;;;;BEV_Ford_B_5 (mazať);	105,5238	6
2	HF45	Top Pipe	232199-1500	TN232100-0141 BEV CH_232199-1500	TN232100-0141 BE	1215-4	15.0	12.0	4.0	200	B	Y			2							2	0,514	;;BEV_Ford_B;;;;;;;BEV_Ford_B_5 (mazať);	105,5238	6
2	HF45	Top Pipe	232199-1500	TN232100-2422 BEV-GT_232199-1500	TN232100-2422 BE	1215-4	15.0	12.0	4.0	200	B	Y				2						2	0,514	;;;BEV_Ford_B;;;;;;BEV_Ford_B_5 (mazať);	105,5238	6
2	HF45	Top Pipe	232199-1500	TN232100-3070 BEV-GT_232199-1500	TN232100-3070 BE	1215-4	15.0	12.0	4.0	200	B	Y					2					2	0,514	;;;;BEV_Ford_B;;;;;BEV_Ford_B_5 (mazať);	105,5238	6
2	HF45	Top Pipe	232199-1500	TN232100-0152 V363_232199-1500	TN232100-0152 V3	1215-4	15.0	12.0	4.0	200	B	Y						2				2	0,514	;;;;;BEV_Ford_B;;;;BEV_Ford_B_5 (mazať);	105,5238	6
2	HF45	Top Pipe	232199-1500	TN232100-2392 MCA_232199-1500	TN232100-2392 MC	1215-4	15.0	12.0	4.0	200	B	Y							2			2	0,514	;;;;;;MCA_Ford_B;;;MCA_Ford_B_2 (mazať);	105,5238	6
2	HF45	Top Pipe	232199-1500	TN232100-3090 MCA_232199-1500	TN232100-3090 MC	1215-4	15.0	12.0	4.0	200	B	Y								2		2	0,514	;;;;;;;MCA_Ford_B;;MCA_Ford_B_2 (mazať);	105,5238	6
2	HF45	Top Pipe	232199-1500	TN232100-3020 HF55_232199-1500	TN232100-3020 HF	1215-4	15.0	12.0	4.0	200	B	Y									2	2	0,514	;;;;;;;;HF55_Ford_B;HF55_Ford_B - FS;	105,5238	6
3	HF45	Degas Pipe	TN232100-1816 HF45321	TN232100-1816 HF45_TN232100-1816 HF	TN232100-1816 HF	1215-4	15.0	12.0	4.0	200	B	Y	1									1	0,257	HF45_Ford_B;;;;;;;;;HF45_Ford_B - FS;	158,2857	6
3	HF45	Degas Pipe	TN232100-2392 MCA321	TN232100-2392 MCA_TN232100-2392 MC	TN232100-2392 MC	1215-4	15.0	12.0	4.0	200	B	Y							1			1	0,257	;;;;;;MCA_Ford_B;;;MCA_Ford_B_2 (mazať);	158,2857	6
3	HF45	Degas Pipe	TN232100-3090 MCA321	TN232100-3090 MCA_TN232100-3090 MC	TN232100-3090 MC	1215-4	15.0	12.0	4.0	200	B	Y								1		1	0,257	;;;;;;;MCA_Ford_B;;MCA_Ford_B_2 (mazať);	158,2857	6

Figure 1. Plan For Every Part database [Source: Authors]

Regarding the evaluation of the current state of logistics processes, an RTLS system with UWB technology was used. This system is used to monitor both logistic and human objects in a defined space in a real time [4]. The RTLS data is stored on the Cloud or in various SQL databases, from which the data can later be exported to digital factory software solutions for the purpose of interpreting and quantifying the data. Before collecting the data, it is necessary to build a structure for the RTLS. The basic elements of the RTLS implementation process are the identification of the processes to be monitored and from which we want to extract data for further detailed analysis. Once the processes of interest have been identified, it is necessary to define the scope, accuracy and refresh rate requirements of the RTLS. Once these requirements are defined, a specific type of RTLS can be selected, such as BLE, UWB, passive/active RFID, Wi-Fi, etc. The selection of the appropriate RTLS technology is a prerequisite for data accuracy [4]. While configuring the RTLS, it is necessary to create zones in the system. If we want to monitor logistic elements, we need to know in which zones they are to move. Once these zones are defined, the appropriate tags and anchors can be allocated to each zone. This allocation has the effect of notifying the user when a tag enters a zone, on the basis of which it is possible to verify the completion of the planned supply circuits. Verification of the completion of the planned supply circuits (Fig. 2) consists of monitoring the following indicators:

- Travelled distance.
- Supply circuit completion.
- Success rate of supply circuit completion.
- Lap time.

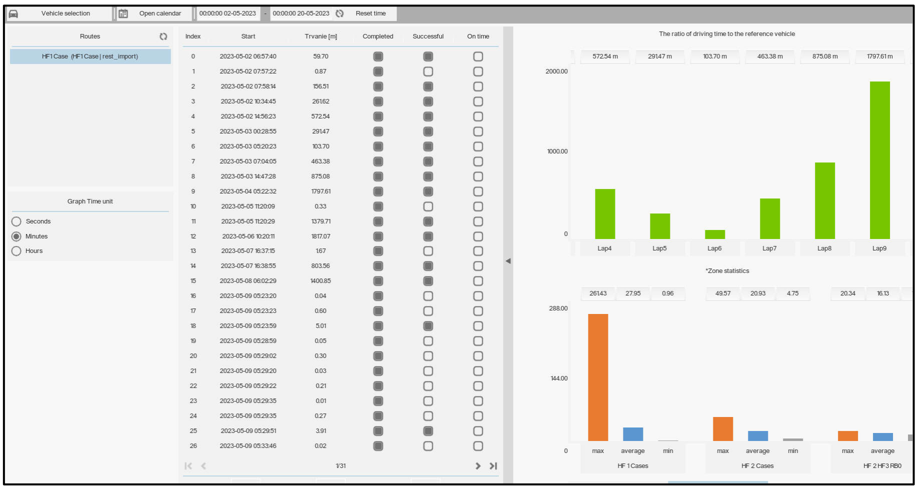


Figure 2. Verification of the completion of the planned supply circuits [Source: Authors]

The evaluation of a supply circuit as successfully completed was conditional on the logistics vehicle having to pass through all the predefined zones assigned to that circuit. Consequently, it was also possible to evaluate the success of the supply circuit in terms of the planned duration of the circuit versus the actual duration. The RTLS data also provided the trajectory of the supply circuits in the form of a spaghetti diagram as well as heat maps in terms of the intensity of staying in a zone (Fig. 3).

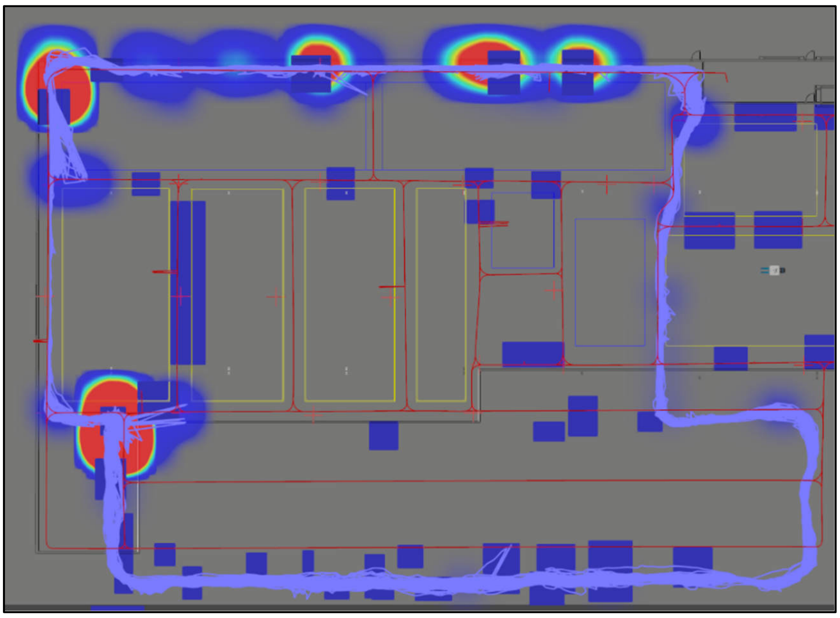


Figure 3. Spaghetti diagram with heat maps of the supply circuit [Source: Authors]

The logistics system worked on the principle of milk-run supply of components from the supermarket to the 4 assembly lines. The logistics operator picked up the parts at the supermarket and then delivered them to the required points of consumption with respect to the delivery schedule. The identified problem was the inability of the logistics operators to deliver the material at the required time and in the required quantity. These problems were also caused by technical constraints in the production hall space as well as incorrect planning of the logistics processes.

3. Creation of a parametric model of the logistics system

Once the RTLS data, as well as the necessary input data, was collected, it was possible to create a parametric model of the logistics system and to create a data structure with the contents and behaviours of the individual elements in question. Once the data elements were created, it was possible to move on to the creation of the hierarchical and logical structure to create a parametric model that reflects the current state and utilization of the logistics system [5,6]. The whole digitization process consists of creating parametric models of the logistics technology, the PFEP parts that entered the assembly process, as well as the creation of the individual material flows through which the parts were delivered to the assembly lines. Due to the logical and hierarchical interconnection between the data nodes in the system, which represented the assembly lines, workstations, assembly units and parts, certain links and relationships were established between these elements. If there is an increase in the planned production volume, the need for parts delivery to the points of consumption will increase, as will the need for delivering finished goods to the locations in the output warehouse. When the input parameters are changed, the system takes into account the individual relationships between the data nodes and recalculates the capacity utilization of the logistics equipment. It is then possible to monitor in the system how a change in the capacity utilization of the logistics equipment will affect other elements in the system.

When creating the supply circuits, it is also necessary to take into account the requirements from the production system, the carrying capacity of the sequential trolleys, the packaging units in which the imported material is packed, as well as the number of parts transported per supply circuit. Other elements to be taken into account are the technical and technological constraints of the system as well as transport constraints. Based on the integration of the collected data described in subsection 1.1, it was possible to create a parametric model of the logistics processes that reflected the current state. The collection of data from the RTLS, as well as the evaluation of this data in the software solution, made it possible to compare the baseline state of the logistics processes based on the data that was collected directly in the logistics system against the actual state based on the plan for delivering parts onto the assembly lines. The following flowchart (Fig. 4) describes the individual steps of creating the parametric model in the digital factory software solution.

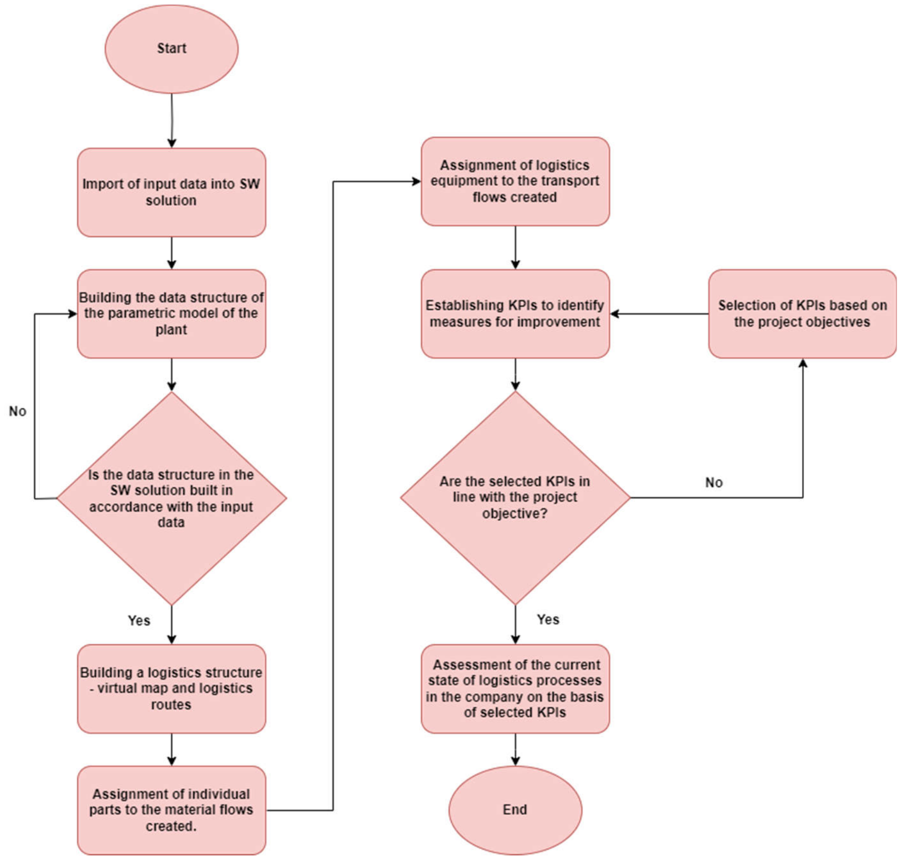


Figure 4. Creation of parametric model in digital factory software solution procedure [Source: Authors]

4. Evaluation of the current state of logistics processes

The output of the creation of the parametric model of logistics processes based on the integration of input data was the evaluation of the current state of logistics processes. This output pointed out the inefficient planning of logistics processes in terms of logistics equipment utilization. Some elements of the technique were under-utilized, while other elements were over-utilized as can be seen on the following page (Fig. 5).

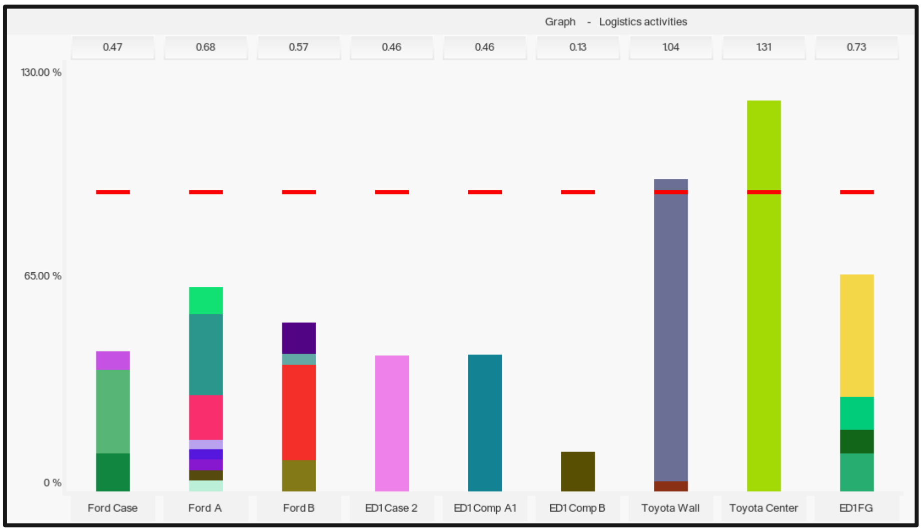


Figure 5. The current state of utilization of logistics vehicles [Source: Authors]

4.1 Creation of optimization variants

Given the outputs of the current situation, it was possible to move on to an analysis of the turnover of parts, of supply circuits in terms of route planning, frequency of deliveries, quantity of delivered parts, etc. After a thorough analysis of the individual factors, it was possible to start identifying improvement potentials and generate optimization variants. In the case of logistics system optimization, two variates were generated to optimize the logistics processes. These variants were based on the results of the analysis of bottlenecks in the system, parts turnover as well as the analysis of the supply circuits.

4.2 Variant no.1

Ford Case, Ford B, and Ford A vehicles delivered parts to the Ford line's individual workstations. In its current state, the Ford Case vehicle was utilized for 47%, the Ford A vehicle was utilized for 68%, and the Ford B vehicle was utilized for 57%. The three vehicles were running similar supply circuits. The Ford Case vehicle was the least utilized vehicle in terms of capacity and was only delivering parts on three circuits. Based on this fact, the supply circuits driven by this vehicle were split between Ford A (Fig. 6) and Ford B vehicles. The reallocation of these circuits also resulted in a reallocation of delivered parts. This step resulted in a saving of one vehicle and an increase in the capacity utilization of Ford A by 19% and Ford B by 28% respectively. This step was possible due to the fact that the vehicles were delivering parts to the same assembly line, but on different workstations. This logic was also applied when analysing the other vehicles occurring in the system. This step achieved a balancing of capacity utilization between the vehicles (Fig. 7) and resulted in a saving of 2 pieces of logistics equipment. In this alternative, it was also proposed to create a two-way street instead of a one-way street over the HF1 and HF2 lines, which would result in a reduction in the length and duration of the selected transport flows.

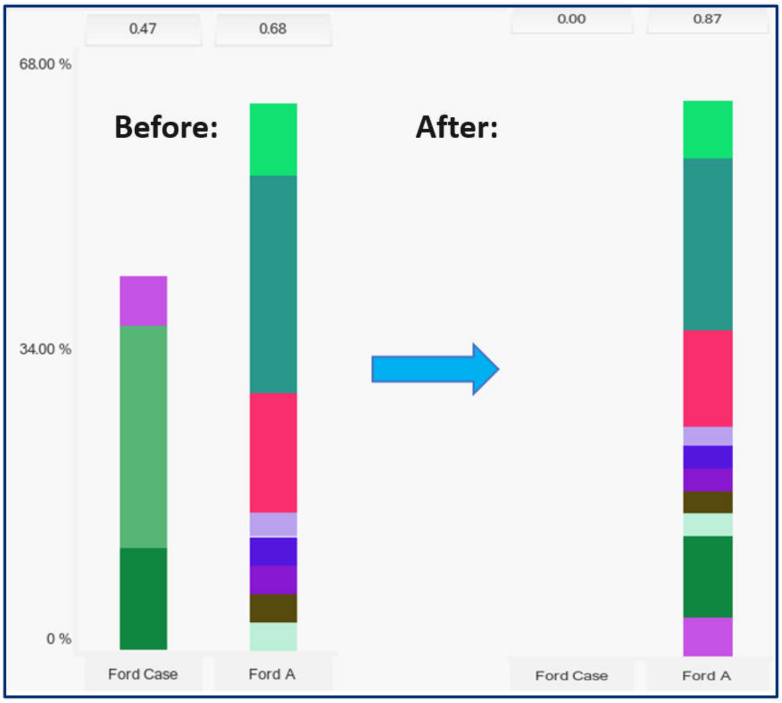


Figure 6. Redistribution of supply circuits [Source: Authors]

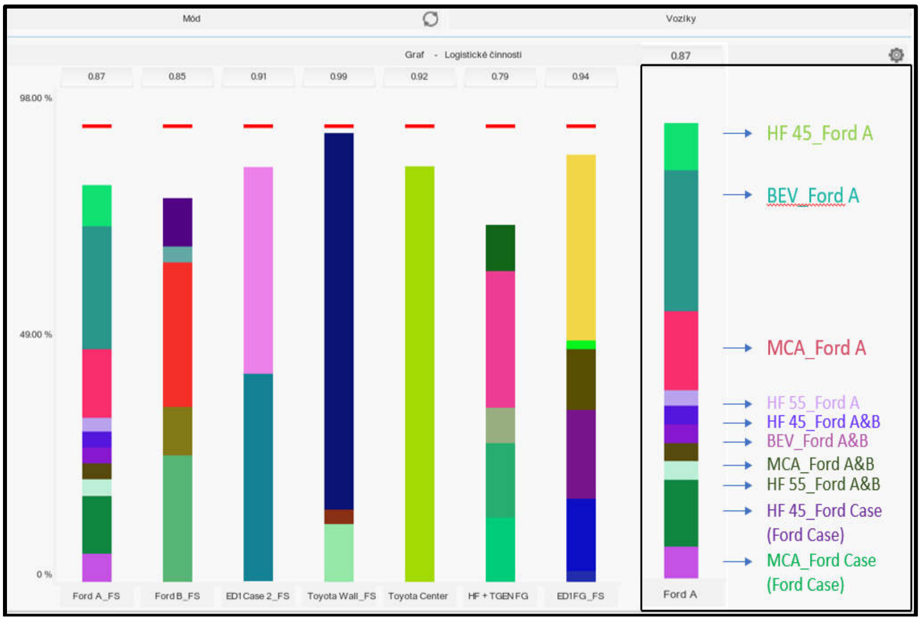


Figure 7. Future state of logistics vehicles utilization [Source: Authors]

4.3 Variant no. 2

In the second variant, it was considered to connect the supply circuits not only within one line, but the selected vehicle would also serve the lines that were located in the immediate vicinity. In this variant, it was also necessary to consider adding additional transitions between these lines, which also resulted in an increase in the capacity utilization of the handling equipment. The number of logistics vehicles required was also reduced from 9 to 7 after the re-planning of the individual circuits (Fig. 8).

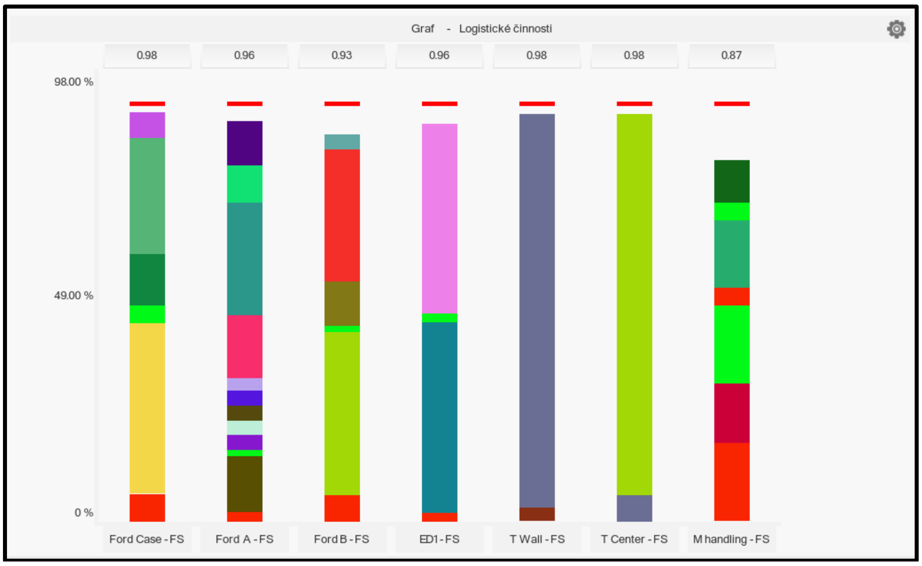


Figure 8 Future state of logistics vehicles utilization [Source: Authors]

4.4 Economic appreciation of the proposed solution

The following data entered into the techno-economic evaluation (Table 1.):

- PIV tugger rental costs.
- Cost of maintenance and charging of the PIV tugger.
- Labour costs of the logistics operator.

Table 1. Economic appreciation of the proposed solution [Source: Authors]

Costs	Piece/ p.a.	Current state	Future state	Savings p.a.
PIV Tugger	12 000€	108 000€	84 000€	94 000€
Maintenance and charging of PIV	5 000€	45 000€	35 000€	
Labour costs of the logistics operator	15 000€	270 000€	210 000€	
SUM		423 000€	329 000	

In its current state, the cost of operating the logistics system was €423,000 per year. After implementation of the improvement proposals, these costs would amount to €329,000 per year, a saving of €94,000 per year. It should be taken into account that the company operates in two shifts, which means that the number of operators who operate the logistics processes in the current state is 18 people. By arriving at the same saving in logistics equipment (2 pcs) in both variants, it would be possible to reduce the number of logistics operators to 14 people. The approximate investment for the project was about 70 000€, therefore the estimated return on investment is estimated in 9 months. The non-financial benefits can include an increase in the efficiency of the logistics system in terms of the reduction of redundant logistics equipment.

5. Conclusion

The aim of the article was to describe the process of digital transformation of logistics processes in the automotive industry using the tools of the digital factory and the digital twin. The sequence of steps of the described process allows a better understanding of the whole process of such a transformation and enables the company to prepare for the digital transformation in terms of collecting the necessary data and then working with it in the environment of the planning tools of the digital factory.

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