A Proposal for the Optimization of Storage Areas in a Selected Enterprise

Prijedlog optimizacije skladišnih prostora u određenom poduzeću

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Summary

The current tough competition prevalent within the market economy is forcing business entities to achieve efficiency in their processes. This also applies to the transfer of goods from point A to point B, which is the subject of transportation. This process is influenced by many factors. It is necessary to not only consider the time,i.e. the fact that the required goods must be delivered in time, but it is also essential to take the financial aspect linked into account, for example, with the cost items such as fuel, salaries etc. These and many other factors also influence the movement of goods within a warehouse, in which the business entity must maximize the space required for the storage of the goods, while minimizing the time necessary for the storage, and equally while optimizing the cost. The aim of this paper follows from the above, which is based on the facts of the course of storage operations in the chosen enterprise,to design an optimal layout of the storage area which should increase the efficiency of the logistical operations.

KEY WORDS

logistics
storage
optimization

Sažetak

Sadašnja oštra konkurencija koja prevladava u tržišnoj ekonomiji prisiljava poslovne subjekte na postizanje učinkovitosti u poslovanju. Ovo se također može primjeniti na prijevoz robe od točke A do točke B, koja je predmet prijevoza. Brojni čimbenici utječu na ovaj proces. Nužno je uzeti u obzir ne samo vrijeme, tj. činjenicu da određena roba mora biti isporučena u roku, već je također nužno uzeti u obzir financijski aspekt, npr. troškove poput goriva, plaća, itd. Ovi i mnogi drugi čimbenici također utječu na kretanje roba u skladištu, u kojima poslovni subjekt mora maksimalno uvećati prostor potreban za skladištenje roba, a umanjiti vrijeme potrebno za skladištenje, te istovremeno optimizirati troškove. Cilj ovog rada slijedi iz gore navedenog, a temelji se na činjenicama tijeka postupaka skladištenja u odabranom poduzeću, a to je dizajnirati optimalni plan skladišnog prostora koji bi povećao učinkovitost logističkih operacija.

KLJUČNE RIJEČI

logistika
skladištenje
optimizacija

INTRODUCTION

At present, logistics extends to various areas of business, either tothe purchase, supply, manufacture, storage, distribution, or other areas. In the simplest way, logistics is defined as the delivery process of goods or servicesto the customer to the agreed place in the required quantity, quality, time, and cost [1].

From the theoretical point of view, the more comprehensive definition, according to which logistics is defined as a discipline dealing with the overall optimization, coordination, and synchronization of all activities within the framework of self-organizing systems, concatenation of which is necessary for the flexible and economical achievement of the final (synergistic) effect [2], [3].

Logistics (related to storage) creates a link between trading partners. The demands for flexible supplying, without the creation

of the supplies, changes the nature of the warehouse inventory strategyin many companies so strongly that it is necessary to entrust this task to external specialized firms [4] - [7].

Therefore, storage is becoming a very advantageous sector of business. Since storage is exclusively a cost element in the logistic chain, due to the different degrees of goods realization, the specialization in storage becomes an attractive source of income for many companies operating in the logistic services [8], [9].

THE FACTS OF THE COURSE OF WAREHOUSE OPERATIONS IN THE SELECTED ENTERPRISE

The selected enterprise is one of the leading companies on the logistic market. Its main focus is to provide comprehensive logistic services in accordance with the protection of the environment and the ISO 9001, ISO 14001, and HACCP certificates. It offers fundamental services such as transportation solutions, logistics, distribution, storage, and others. The company has subsidiaries in four Central European countries, i. e. Slovakia, the Czech Republic, Poland and Hungary. The company has the warehouses of various sizes in these countries that are suitable for Euro Pallets with the standard pallet space height of 180 cm.

We will focus on a more detailed research of the warehouse in Senec, since it is a storage area which is the largest from the viewpoint of the pallets number, and it also occupies an area of about 10,000 m^2. In addition to the dry storage area, where the temperature regime is set to a temperature of +15°C to +25 °C, it offers a cold storage area as the only one of the warehouses that has such a cold storage area that has adjustable temperatures for its customers as well. This type of storage allows them to store a various range of products, which requirereduced temperatures ranging from +2 °C to +6 °C. This includes, for example, the storage of foodfor which the company obtained the IFS certificate. At the same time, the store in Senec has hydraulically adjustable ramps and, as far asproperty protection is concerned, it is secured by electronic security systems, video surveillance, and a direct connection to the ARC (the alarm receiving centre).

The next step is order picking, which means preparing orders for shipment. One of the following systems can be chosen: either FIFO (First In First Out) or FEFO (First Expired, First Out). The preparation of the orders for shipment is carried out according to the customer's requirements, where the defined units (such as pallets, cartons, or pieces) are distinguished. The barcode readers, the serial numbers, batches, or pallet numbers are made use of. The last procedure of the order picking takes place on the packaging line.

Depending on the type of received goods, the materials for storage include Europallets, shelves and shelving systems, which comprise about 75 % of the storage area. The storage area is divided into approximately 12 equal areas. Two of them are separated because they representthe storage areas for refrigerated products, which require lower storage temperatures. The following figure (*figure 1*) describes the layout of the warehouse.

As we can see in *figure 1*, the storage area is divided into 12 parts depending on the main routes of the goods. This information is presented in more detail in the table below.

Table 1. The layout of the storage area

Storage Area Number	Main Route	Storage Area Number	Other Routes
1	Bratislava (BA)	8	Other goods
2	Žilina (ZA)	9	Other goods
3	Košice and Prešov (KE, PO)	10	Other goods
4	BanskáBystrica and Nitra (BB, NR)	11	Cold storage
5	Trenčín (TN)	12	Cold storage
6	Trnava (TT)		
7	Liptovský Mikuláš and Poprad (LM, PP)		

Source: authors

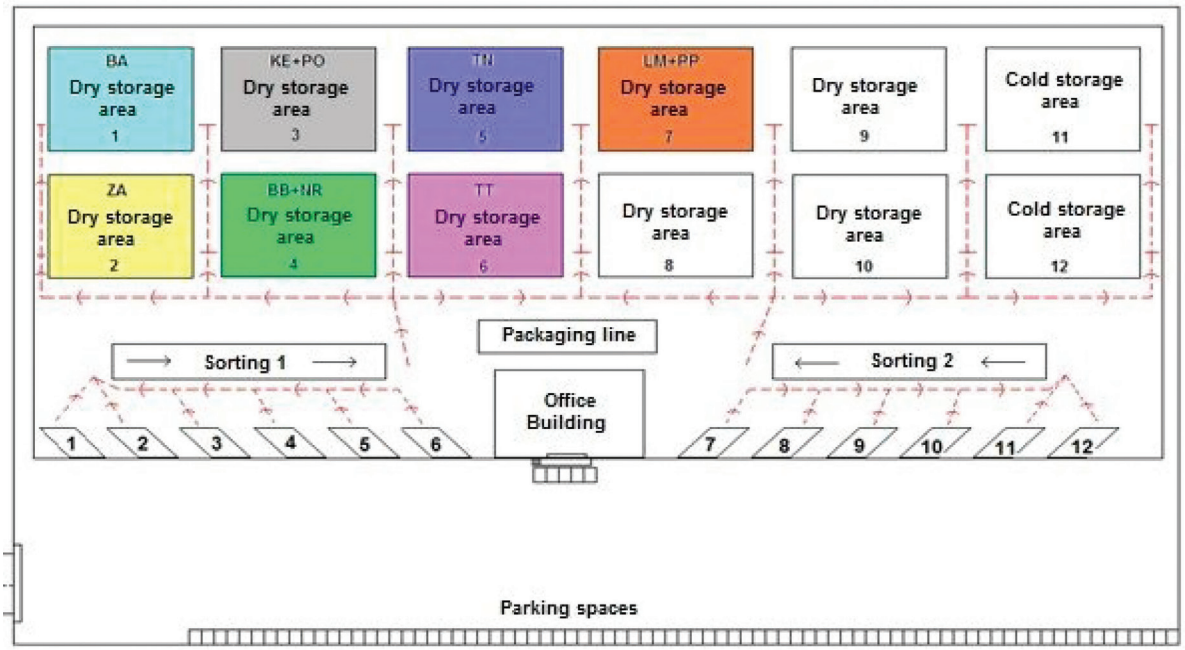


Figure 1 The current layout of the storage area in the selected enterprise

Source: authors

The goods from the main routes are stored in areas 1 to 7. Storage areas 8, 9, and 10 are determined for the goods from other routes or for other goods that are stored on Europallets. Storage areas 11 and 12 are intended for cold storage products. There are 12 hydraulic loading ramps used for loading and unloading the stored goods in the warehouse. Hydraulic ramps 1 to 7 are intended for the loading and unloading of those goods from the main routes and the other ramps are used, though that depends on the workload of the other ramps.

The following section is focused on the analysis of the distances needed for unloading the goods and their transport to the sorting lines, which serve for the sorting of the delivered goods. The company has two sorting lines, one of which serves for ramps 1 to 6 and the other which serves for ramps 7 to 12. Forklift trucksare used during this process; the average speed of these forklift trucks is 8.5 km/h (when they are loaded) and 11 km/h (when they are empty). A truck can transport an average of 32 pallets in its storage area and a cargo vehicle can transport about 15 pallets.

It is necessary to traverse the distance of 11.1m to unload one pallet from the truck and its transport to the sorting line,providing that the received goods are on ramp 1.The forklift truck traversesthe distance of about 710.4 metres between the ramp and the sorting line when it unloadsthe truck (which contains 32 pallets). The distance from ramp 1 to the sorting line and back is ca. 333.0 m., when 15 pallets are unloaded from the cargo vehicle.

Within the context of the distances at the first sorting line, the least number of metres is traversed when moving the goods from ramp 2, which is located closest to the first sorting line. In total, the greatest distance is traversed by the forklift trucks from ramp 7 to the second sorting line and back; that is 4 435.2 m when unloading the whole truck, and 2 079.0 m when unloading 15 pallets from the cargo vehicle.

Table 4 shows the distance necessary for unloading the goods from the truck or the cargo vehicle, and also the transport of the goods from the given vehicle to the sorting line expressed in time units. Ten seconds needed for lifting and storing the goods on the shelf or the shelving system; these time periods are included in the total time.

Table 2 The distances to the sorting Lines during the goods unloading (in metres)

Ramp 	Distance to the Sorting Line for the Transport of 1 Pallet	Drive Back 	Total	Truck Unloading 	Cargo Unloading 
1	11.1	11.1	22.2	710.4	333.0
2	9.3	9.3	18.6	595.2	279.0
3	20.4	20.4	40.8	1 305.6	612.0
4	34.2	34.2	68.4	2 188.8	1 026.0
5	50.8	50.8	101.6	3 251.2	1 524.0
6	64.7	64.7	129.4	4140.8	1 941.0
7	69.3	69.3	138.6	4 435.2	2 079.0
8	55.5	55.5	111.0	3 552.0	1 665.0
9	40.7	40.7	81.4	2 604.8	1 221.0
10	22.1	22.1	44.2	1 414.4	663.0
11	10.0	10.0	20.0	640.0	300.0
12	11.1	11.1	22.2	710.4	333.0
Total	X	X	798.4	25 548.8	11 976.0

Source: authors

Table 3 The time necessary for thegoodstransport to the sorting lines (in seconds)

Ramp 	Time Needed for the Transport of 1 Pallet	Drive Back 	Total	Truck Unloading 	Cargo Unloading 
1	14.7	3.6	18.3	585.6	274.5
2	13.9	3.0	16.9	540.8	253.5
3	18.6	6.7	25.3	809.6	379.5
4	24.5	11.2	35.7	1 142.4	535.5
5	31.5	16.7	48.2	1 542.4	723.0
6	37.4	21.2	58.6	1 875.2	879.0
7	39.4	22.7	62.1	1 987.2	931.5
8	33.5	18.2	51.7	1 654.4	775.5
9	27.2	13.3	40.5	1 296.0	607.5
10	19.4	7.2	26.6	851.2	399.0
11	14.2	3.3	17.5	560.0	262.5
12	14.7	3.6	18.3	585.6	274.5
Total	X	X	419.7	13 430.4	6 295.5

Source: authors

Table 4 confirms that the transport of one pallet from the truck to the second sorting line and back at ramp 7 is the most time consuming. Ramp 6 is the farthest from the first sorting line. The transport of the goods from all over the truck to the first sorting line requires the time of 31 minutes (1875.2 seconds) and, as far as the Cargo vehicle is concerned, it takes about 15 minutes (879.0 seconds).

If we focus on the transfer of the goods from the sorting line directly to the designated storage area, the following table clearly shows the two furthest storage areas. It is the storage area intended for Bratislava (181.2 m) and Žilina (127.6 m).

PROPOSAL FOR AN OPTIMAL STORAGE AREA LAYOUT

Based on the previous analysis, it can be concluded that the use of the hydraulic ramps is inefficient, which results in distance and time losses during the movement of the goods. Some of the routes are traversed unnecessarily, which affects the larger volume of financial means for fuel and this also leads to the fact that the vehicles are worn out. A more efficient solution would be to optimize the usability of the ramps according to the following figure (*figure 2*), which describes a proposal for a new storage area layout.

The number of the hydraulic ramps (with regard to their workload) is considered as sufficient; therefore their number does not have to be increased. However, it is necessary to use them more effectively depending on the overall arrangement of the warehouse. At present, ramps 1 – 7 are used for the unloading and loading of those goods from the main routes and the other ramps (8 – 12) are used, depending on the employment of the other ramps. We propose that ramps 1 – 7 are intended for the goods from the main routes. Ramps 1 and 2 would be prioritized for the goods going to Bratislava and Žilina. Ramps 3 and 4 would receive the goods for Košice, Prešov, Banská Bystrica and Nitra. The goods going to Trenčín and Trnava would be received by ramps 5 and 6. In the case where hydraulic ramps 1 – 6 were fully occupied, ramp 7 would be available. Ramps 8, 9, and 10 would be intended for unloading and loading the goods from the other routes.

Table 4 The distances from the sorting lines to the storage areasfor the goods tansport (in meters)

Route 	Distance to the Storage Area for the Transport of 1 Pallet	Drive Back 	Total	Truck Unloading 	Cargo Unloading 
BA	90.6	90.6	181.2	5 798.4	2 718.0
ZA	63.8	63.8	127.6	4 083.2	1 914.0
KE, PO	53.6	53.6	107.2	3 430.4	1 608.0
BB, NR	27.7	27.7	55.4	1 772.8	831.0
TN	53.6	53.6	107.2	3 430.4	1 608.0
TT	27.7	27.7	55.4	1 772.8	831.0
LM, PP	51.8	51.8	103.6	3 315.2	1 554.0
Total	X	X	737.6	23 603.2	11 064.0

Source: authors

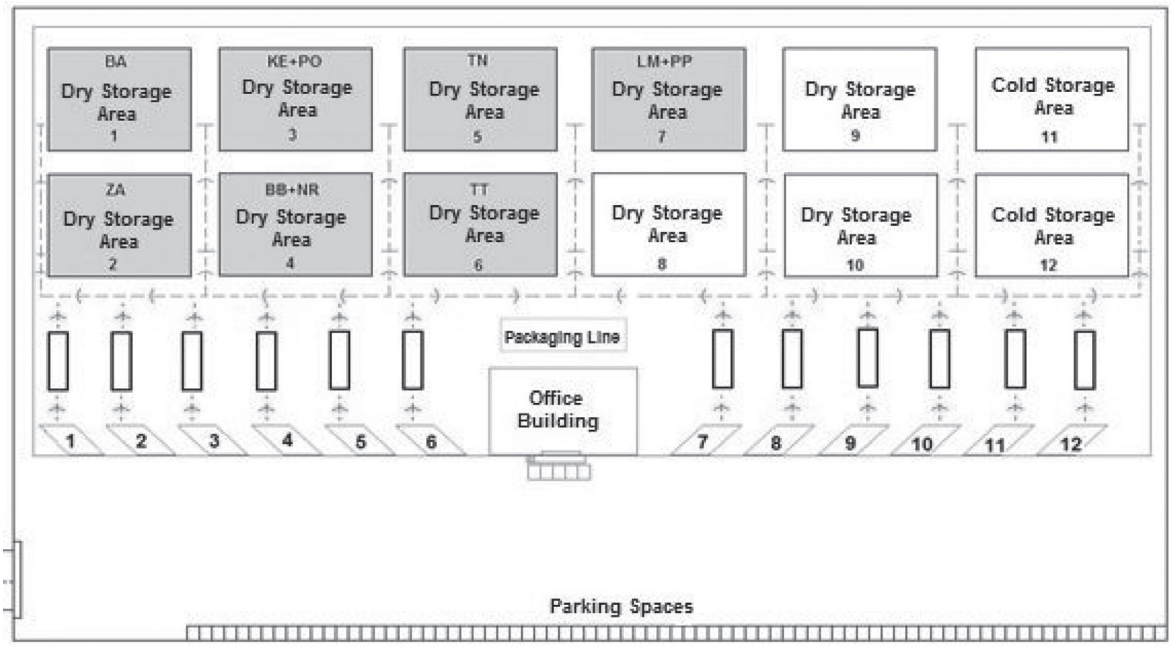


Figure 2 The proposal for a new storage area layout in the analysed enterprise

Source: authors

A solution to the problem of the inefficient unloading of the refrigerated products on ramps 1 -7, which are far away from the cold storage area, could be to utilize ramps 11 and 12, preferably for the refrigerated products from the main routes, but also even from the other directions. This would optimize the flow of the goods and then the distance losses would be eliminated; at present, some routes are traversed several times.

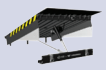
There are two sorting lines in the warehouse. One is intended for ramps 1 – 6 and the other for ramps 7 – 12. Their location is considered inappropriate, since, as follows from the original layout of the warehouse and from the tables of distances expressed in metric and time indicators necessary for unloading the trucks or the Cargo vehicles, the forklift trucks must traverse the greatest distances during the goods unloading from ramps 4 – 9. The needed time is, at least, double as well. At the same time, the sorted goods are accumulated and the forklift trucks do not have the space for manipulation, which results in the loss of time.

On the basis of the proposal for the new storage area layout, a more efficient solution would be to increase the number of the sorting lines. This is a solution according to which each hydraulic ramp would have its own sorting line. Such a proposal means certain costs in rebuilding and staff, which is sufficient in the enterprise. The result would be the increase of the efficiency of the logistic operations, which would ultimately mean a gradual reduction in costs [10].

The distances and times needed for unloadingthe goods and their transfer to the newly proposed sorting lines are presented in the following tables (*table 5, 6*).

The distances are equal because each hydraulic ramp has its own sorting line. In comparison to the original variant, the distances traversed are minimal. *Table6*shows the time savings facilitated by the newly designed model.

Table 5 The distances to the sorting lines during unloading the goods after the new arrangement of the storage area (in metres)

Ramp 	Distance to the Sorting Line for the Transport of 1 Pallet	Drive Back 	Total	Truck Unloading 	Cargo Unloading 
1	6.0	6.0	12.0	384.0	180.0
2	6.0	6.0	12.0	384.0	180.0
3	6.0	6.0	12.0	384.0	180.0
4	6.0	6.0	12.0	384.0	180.0
5	6.0	6.0	12.0	384.0	180.0
6	6.0	6.0	12.0	384.0	180.0
7	6.0	6.0	12.0	384.0	180.0
8	6.0	6.0	12.0	384.0	180.0
9	6.0	6.0	12.0	384.0	180.0
10	6.0	6.0	12.0	384.0	180.0
11	6.0	6.0	12.0	384.0	180.0
12	6.0	6.0	12.0	384.0	180.0
Total	X	X	144.0	4 608.0	2 160.0

Source: authors

Table 6 The times required for the transport of goods to the sorting lines after the new arrangement of the storage area (in seconds)

Ramp 	Time Required for the Transport of 1 Pallet	Drive Back 	Total	Truck Unloading 	Cargo Unloading 
1	12.5	2.0	14.5	464.0	217.5
2	12.5	2.0	14.5	464.0	217.5
3	12.5	2.0	14.5	464.0	217.5
4	12.5	2.0	14.5	464.0	217.5
5	12.5	2.0	14.5	464.0	217.5
6	12.5	2.0	14.5	464.0	217.5
7	12.5	2.0	14.5	464.0	217.5
8	12.5	2.0	14.5	464.0	217.5
9	12.5	2.0	14.5	464.0	217.5
10	12.5	2.0	14.5	464.0	217.5
11	12.5	2.0	14.5	464.0	217.5
12	12.5	2.0	14.5	464.0	217.5
Total	X	X	174.0	5 568.0	2 610.0

Source: authors

Table 6 shows the time required for the transport of the goods from the truck or the cargo vehicle directly to the sorting lines after the new arrangement of the storage area. Inboth the original arrangement and the proposed one, the 10 seconds (that are needed for lifting and storing the goods) are counted. The traversed distances and the time data indicate that the times are equal.

Table 7 describes the distances from the newly proposed sorting lines to the storage areas of the main routes traversed during the movement of the goods during their storage.

The main difference from the original arrangement lies in the better usability of the hydraulic ramps. In the original alternative, nearly 800 m from all the ramps to the sorting lines were required for unloading one pallet from the truck or the cargo vehicle (see *table 2*). The forklift trucks had to traverse unnecessarily long distances from some of the ramps, which affected the fuel consumption and time.

The new model includes the construction of new smaller sorting lines. Each ramp would have its own sorting line. As follows from *table 5*, in this case, the distance when unloading would reduce to 6 metres. Based on the following table comparing the distances required for unloading the pallets from the vehicle toward the sorting lines, a significant saving of distance traversed can be seen.

In comparison to the original layout, there would be a saving of about 650 metres during the unloading of one pallet from all of the ramps. When converted to the unloading of the entire truck(which is 32 pallets on average), there would be the difference between the distances of about 21 km in the newly proposed model and as far as the cargo vehicle is concerned, it would be a savings of about 10 km. In addition to the savings of distances travelled, there is also an increase in the efficiency of the time required for the work (*table 9*).

Table 7 The distances to the storage areas when transporting the goods (in metres)

Route 	Distance to the Storage Area for the Transport of 1 Pallet	Drive Back 	Total	Truck Unload 	Cargo Unload 
BA	72.1	72.1	144.2	4 614.4	2 163.0
ZA	30.5	30.5	61.0	1 952.0	915.0
KE, PO	45.3	45.3	90.6	2 899.2	1 359.0
BB, NR	27.7	27.7	55.4	1 772.8	831.0
TN	50.8	50.8	101.6	3 251.2	1 524.0
TT	18.5	18.5	37.0	1 184.0	555.0
LM, PP	48.0	48.0	96.0	3 072.0	1 440.0
Total	X	X	585.8	18 745.6	8 787.0

Source: authors

Table 8 The comparison of the distances to the sorting line during the unloading of the goods (in metres)

Ramp 	Distance to the Sorting Line for the Transport of 1 Pallet		Truck Unloading 		Cargo Unloading 	
	Original	Proposed	Original	Proposed	Original	Proposed
1	22.2	12.0	710.4	384.0	333.0	180.0
2	18.6	12.0	595.2	384.0	279.0	180.0
3	40.8	12.0	1 305.6	384.0	612.0	180.0
4	68.4	12.0	2 188.8	384.0	1 026.0	180.0
5	101.6	12.0	3 251.2	384.0	1 524.0	180.0
6	129.4	12.0	4 140.8	384.0	1 941.0	180.0
7	138.6	12.0	4 435.2	384.0	2 079.0	180.0
8	111.0	12.0	3 552.0	384.0	1 665.0	180.0
9	81.4	12.0	2 604.8	384.0	1 221.0	180.0
10	44.2	12.0	1 414.4	384.0	663.0	180.0
11	20.0	12.0	640.0	384.0	300.0	180.0
12	22.2	12.0	710.4	384.0	333.0	180.0
Total	798.4	144.0	25 548.8	4 608.0	11 976.0	2 160.0
Difference	654.4		20 940.8		9 816.0	

Source: authors

Table 9 The Comparison of Times Required for the Transport of the Goods to the Sorting Lines (in Seconds)

Ramp 	Time Required for the Transport of 1 Pallet		Truck Unloading 		Cargo Unloading 	
	Original	Proposed	Original	Proposed	Original	Proposed
1	18.3	14.5	585.6	464.0	274.5	217.5
2	16.9	14.5	540.8	464.0	253.5	217.5
3	25.3	14.5	809.6	464.0	379.5	217.5
4	35.7	14.5	1 142.4	464.0	535.5	217.5
5	48.2	14.5	1 542.4	464.0	723.0	217.5
6	58.6	14.5	1 875.2	464.0	879.0	217.5
7	62.1	14.5	1 987.2	464.0	931.5	217.5
8	51.7	14.5	1 654.4	464.0	775.5	217.5
9	40.5	14.5	1 296.0	464.0	607.5	217.5
10	26.6	14.5	851.2	464.0	399.0	217.5
11	17.5	14.5	560.0	464.0	262.5	217.5
12	18.3	14.5	585.6	464.0	274.5	217.5
Total	419.7	174.0	13 430.4	5 568.0	6 295.5	2 610.0
Difference	245.7		7 862.4		3 685.5	

Source: authors

It follows from Table 10 that the result of the proposed model allows the unloading of the pallets to be more efficient, i.e. reducing the time from 224 minutes (13,430.4 seconds) to 93 minutes (5,568.0 seconds), which would lead to the saving of time when unloading the trucks at the ramps by about 131 minutes (7,862.4 seconds) and about 61 minutes (3685.5 seconds) in case of the cargo vehicles.

The previous tables express the saving of distance and time, which occur during the movement of the pallets from the trucks or the cargo vehicles to the sorting lines. The following calculation details the saving of distance when transporting the goods from the sorting lines to the storage areas in accordance with the individual routes (*table 10*).

The proposed model of the warehouse logistics at the same time brings, savings related tothe movement of goods between the sorting lines and the storing areas, apart from the saving of the distance and time between the transportation of the good from the truck to the sorting lines. When storing the 32 pallets from a fully loaded truck, there is a saving of the traversed distances from the point of view of the main routes, according to the previous table, of nearly 5 km (4,857.6 m) and more than 2 km (2,277.0 m) for the cargo vehicles. The most significant saving would relate to the storage of those goods intended for Žilina. The savings would be more than 2 km (2,131.2 m) with the truck and nearly 1 km (999 m) with the cargo vehicle. There would be space for dispatching a higher number of vehicles, due to the distance and time savings. Assuming the new model is used, it would be possible to provide for nearly a double truck unloading, in case of exclusive truck unloading during one continuous eight-hour work shift. The doubling would occur even in case of the exclusive goods beingunloadedfrom the cargo vehicles.

Table 10 The comparison of the distances when storing the goods (in metres)

Route 	Distance to the Storage Area for the Transport of 1 Pallet		Truck Unloading 		Cargo Unloading 	
	Original	Proposed	Original	Proposed	Original	Proposed
BA	181.2	144.2	5 798.4	4 614.4	2 718.0	2 163.0
ZA	127.6	61.0	4 083.2	1 952.0	1 914.0	915.0
KE, PO	107.2	90.6	3 430.4	2 899.2	1 608.0	1 359.0
BB, NR	55.4	55.4	1 772.8	1 772.8	831.0	831.0
TN	107.2	101.6	3 430.4	3 251.2	1 608.0	1 524.0
TT	55.4	37.0	1 772.8	1 184.0	831.0	555.0
LM, PP	103.6	96.0	3 315.2	3 072.0	1 554.0	1 440.0
Total	737.6	585.8	23 603.2	18 745.6	11 064.0	8 787.0
Difference	151.8		4 857.6		2 277.0	

Source: authors

CONCLUSION

From the economical point of view, the contribution of the newly proposed model should result in the reduced costs in different areas, in addition to the increased efficiency of the logistics operations as well. Namely, this would include the cost of fuel, the cost of thevehicles transporting the stored goods and the related time losses. More concrete numbers will be available only after a certain time from the implementation of the solution. At least half of the savings of fuel are assumed as a result of the shortening of the traversed distances.At the same time, less wear and the reduced coston the service of the forklift trucks are assumed. In addition to these benefits, the time for which the vehicle must stand still during the unloading will be shortened by implementing the new model. In that case, there is a chance to dispatch a higher number of orders per day. As a consequence of such measures, the final result could be the increase of the enterprise income [11]-[17].

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