EVALUATION OF A COURIER COMPANY'S OPERATIONS BY DECISION ANALYSIS METHODS

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Abstract

The main objective of this paper is to point out all deficiencies within the consignment sorting process. The article suggests an appropriate alternative for unloading, reloading, sorting, and loading of consignments, using the multiple-criteria decision making. Within the decision-making process, the emphasis is put on energy consumption and investment costs in the case of using new handling equipment. The proposed solution will reduce the sorting time, decrease the risk of consignment damage, and increase safety and smoothness of work in the depot.

Keywords: Sorting process, multiple-criteria decision making

1. INTRODUCTION

The solution proposed by the article is focused on identification of deficiencies related to the use of a roller conveyor in a depot during the morning and the evening consignments sorting in the depot no. 652. The depot ensures transportation of consignments to 13 smaller areas (**Figure 1**), referred to as routes. Each route in the depot is assigned a separate sector (site), designated with a number. Individual routes in the depot are separated from other routes by fictive lines on the ground. Sector size depends on the quantity of parcels falling to a particular route. **Figure 1** shows the depot layout and consignment sectors.

Figure 1 Depot layout for the morning sorting

The evening sorting (**Figure 2**) and loading is carried out by employees who load consignments according to a designated number of an acceptance depot. Cages are lined in two rows, from the lowest to the highest depot numbers, with the exception of first two cages designated as 660, heading to Bratislava, and without cage 652, as the parcels designated with this number do not have to be sent anywhere - they stay on the pallet over night at the end of a roller conveyor. In the morning, these parcels are scanned only as items accepted to a depot. At the end of a row, there are Export, HUB, and Export-DE cages. The Export cage is intended for parcels to be sent out of the Slovak Republic, but only within the EU. Parcels heading out of the EU are placed into the HUB cage. This cage also contains guaranteed parcels for which a cage must be also designated with the "Express" label, a box with replaceable envelopes, cash on delivery and acceptance protocols, accounting

documents of cash on delivery payments and cash, and it may also contain parcels incorrectly sorted. The Export-DE cage is intended exclusively for parcels heading to Germany.

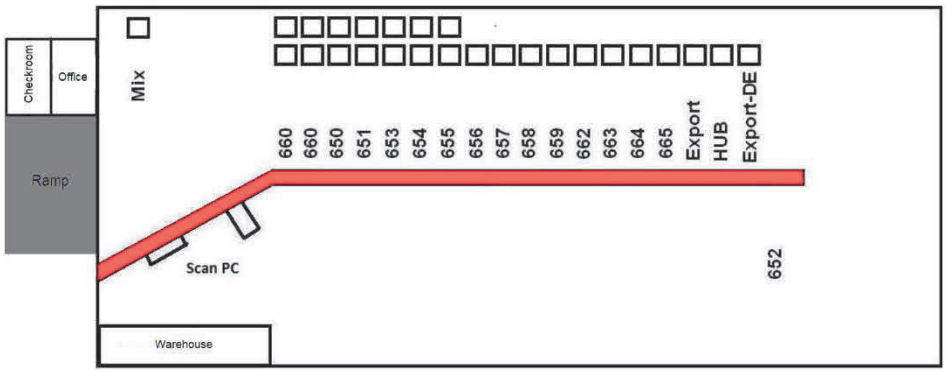

Figure 2 Depot layout for the evening sorting

2. IDENTIFICATION OF DEFICIENCIES OF THE CURRENT SORTING METHODPICTURES, EQUATIONS, TABLES

At present, sorting is carried out using a roller conveyor. It enables handling piece consignments, transportation of material inside manufacture halls or warehouses. Conveyor's structure is adjusted for easy manipulation [1]. Disadvantages of a roller conveyor used in the depot are as follows:

- *Constant speed*. A roller conveyor track is set to a constant speed which is not suitable for the morning and evening consignments sorting. When a larger amount of consignments is to be transported, couriers need more time to take over the consignments. If a roller track movement is set to a constant speed, couriers are not able to watch moving consignments on the belt, place them in determined sectors, and scan them at the same time. Parcels not caught and placed to a correct site move forward and accumulate at the end of the belt, where they obstruct the work of other couriers. They often fall off the belt and get damaged.

- *Missing guide rails*. There is only one small guide rail on the roller track. Parcels unusually get stuck there, often causing accumulation and twisting of parcels. In such case, an employee must approach this site and release the stuck parcels. Twisted parcels move from the track centre to the roller track side, fall on the ground and get damaged. The proposed solution - installing higher, funnel-shaped guide rails would prevent from several mishaps and time loss during the parcel directing process.

- *Inappropriate spacing between rollers*. In some cases, rather small parcels, light parcels, envelopes, oval parcels, and similar items are transported in a depot. If the spacing between the rollers is too long, parcels stuck between the rollers and an employee's intervention is required; sometimes parcels even fall between the rollers down on the ground. In such cases, parcel content or cardboard packaging is damaged. Proposed solution - use of a conveyor with a rubber belt.

- *Dead end of a roller track*. A roller track in a depot is driven by electric motors, with 5m spacing. The last 5 meters of the track is free of any electric drive and rollers are freely placed in a housing. When accumulation of parcels occurs and couriers are busy, parcels fall off. The track is equipped with a manual brake to stop the track instantly, if necessary. Proposed solution - to install a parcel quantity sensor for the purpose of automatic stop of a roller track movement and replacement of a finite roller track with an infinite roller track.

- *Loading and unloading of parcels in the exterior*. During the morning and evening reloading, parcels are unloaded in the exterior. They are relocated by employees from the exterior to a conveyor. Proposed solution - the use of a telescopic conveyor with a rubber conveyor belt or an expendable roller track that may be

positioned to reach even inside a vehicle. In both cases it is necessary to reconstruct the entrance to the depot, extending the door width and building a ramp suitable for the placement of conveyors.

3. PROPOSED ALTERNATIVE SOLUTIONS OF CONSIGNMENT SORTING

An optimal solution was chosen while considering the conveyor location and type and the consignments transport direction. The selection will be carried out while assessing 3 options. Calculation of a conveyor's output is carried out according to Martínek [2]. The first alternative presents consignment sorting with concurrent placement of a roller conveyor (**Figure 2**). The second alternative - a circulating roller conveyor (**Figure 3**), and the third alternative - a combined conveyor (**Figure 4**).

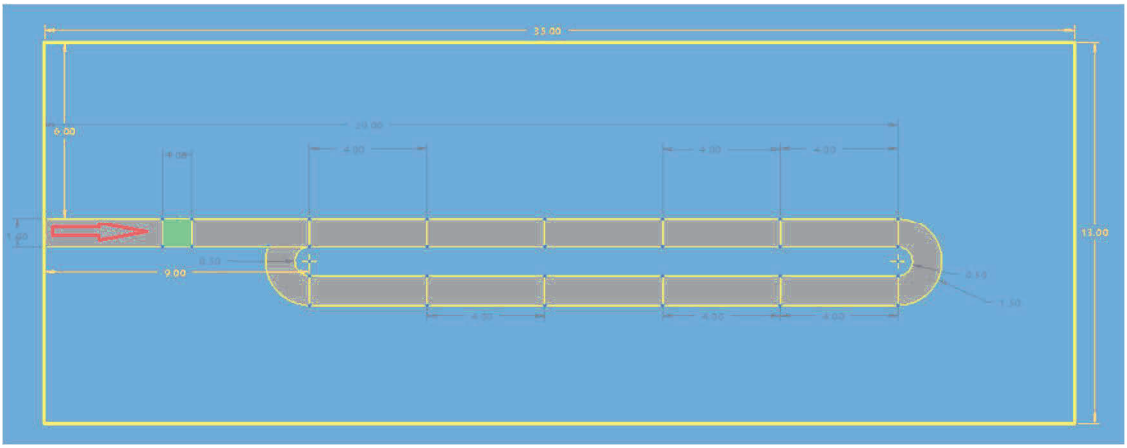

Figure 3 Circulating roller conveyor - Alternative 2

Conveyors are arranged so that a telescopic conveyor or an expandable roller track may be attached to them. In the case of a combined conveyor, straight sections are formed by a rubber conveyor belt and arch sections of a conveyor track are formed by rollers (**Figure 4**).

Figure 4 Combined conveyor- Alternative 3

Table 1 shows the strengths and weaknesses of three assessed alternative solutions of consignment sorting.

In the proposed alternative 3 of the sorting solution, a consignment handling procedure was characterized. **Table 1** shows the strengths and weaknesses of the assessed sorting alternatives and **Table 2** shows the basic evaluation criteria and input data for the selection of the most appropriate alternative. The basic evaluation criteria included:

Investment costs. They were determined, in the case of a roller conveyor, on the basis of the quantity and price of electric motors. In the case of a combined conveyor, they were determined on the basis of the price of electric motors and of a conveyor belt, as well as support rollers. A roller conveyor operation requires:

- to buy twelve 1.1 kW motors, and in arch section two 1.1 kW electric motors,
- the price of 1 Siemens electric motor is EUR 178 and the price of 14 electric motors is EUR 2,498.

Table 1 Analysis of strengths and weaknesses of the assessed alternatives

ALTERNATIVES	STRENGTHS	WEAKNESSES
V1 Currently used roller conveyor	Simple structure	Parcels accumulation at the end of a track
	Low spatial requirements	Damage to parcels when they fall off a track
	Flexibility for roller track adjustment	Long spacing between rollers
V2 Circulating roller conveyor	Modular structure made of segments	Higher noise level
	Shorter spacing between rollers	Low friction between parcels and rollers
	Flexibility for roller track adjustment	Reduced space for couriers
V 3 Combined conveyor	Lower noise level	Higher maintenance requirements
	Higher safety	Reduced space for couriers
	Parcels do not slip on a belt	-
	Elimination of consignments falling off the conveyor	-
	Telescopic extension of a conveyor	-

A belt conveyor consists of three main parts:

- the first part is 4 metres long and the operation thereof requires a 1.1 kW Siemens motor.
- the second part is 24 metres long and the third part is 20 metres long. A conveyor belt driving requires a 4kW MEZ motor for the price of EUR 249.
- a combined conveyor has two arch roller parts driven by a 1.1 kW motor. The total cost of all electric motors is EUR 1,032.

Power consumption is determined according to the calculation from the output of electric motors according to [2] and the power consumption:

- when a roller conveyor is used, the power consumption per hour at the full capacity will be 15.4 kW,
- when a combined conveyor is used, the power consumption will be 11.3 kW.

Flexibility. All assessed conveyor structures are stabile. In the case of a roller conveyor, a conveyor may be extended using an expendable roller track (**Figure 5**) with the structure formed by joint-connected sections with adjustable track length [3]. In the case of a combined conveyor, a telescopic conveyor may be used, with adjustable height and length, and with the maximum carrying capacity of up to 100 kg. A telescopic conveyor may be extended in length to a triple size (**Figure 6**), facilitating thus loading and unloading of consignments directly from or to a vehicle [4].

Figure 4 Expandable roller conveyor [4]

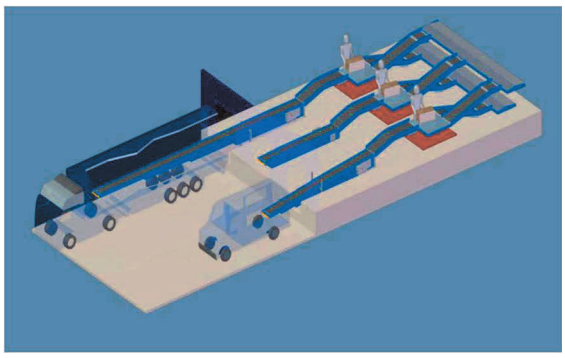

Figure 5 Telescopic belt conveyor [5]

Noise level during the operation. In the case of roller conveyors, the noise is produced by rotation of rollers and chain gears. When combined conveyors are used, the noise level is lower due to reduced number of rollers.

Safety - for conveyors, safety assessment is focused on occupational safety of operators and the risk of injury. In the case of roller conveyors, a person's arm may be caught between the rollers. In the case of a combined conveyor, the risk of injury is lower, as majority of the track is formed by a conveyor belt.

Table 2 Table of input data for the multiple-criteria decision making

Evaluation criterion	**Alternatives**		
	V1	V2	V3
	Finite conveyor	Circulating conveyor	Combined conveyor
K1 - investments	EUR 0	EUR 2,498	EUR 1,032
K2 - power consumption	4.4 kW	15.4 kW	11.3 kW
K3 - flexibility	40%	90%	90%
K4 - noise level	60%	80%	30%
K5 - safety	60%	70%	90%

4. IMPLEMENTATION OF DECISION ANALYSIS METHODS WITHIN THE SELECTION OF OPTIMAL CONSIGNMENT HANDLING EQUIPMENT

At present, multiple-criteria decision-making methods play more and more important role in the selection of optimal handling equipment [6,7,8]. Almost none of our decisions are affected solely by a single criterion. An important step within the decision-making is the determination of criteria and subsequent determination of criteria preferences, or weights. Therefore, within the selection of an optimal conveyor structure, 5 basic criteria were determined. In the decision-making process, 2 decision-making methods were used to determine the most optimal solution for consignment handling. The first method is the Decision Matrix Method (DMM), in which the weight αi was specified on the basis of the importance (priority) and a numerical value of the point scale ranges from 1 to 10 for each evaluation criterion. A similar method is used to assign a weight (usefulness) u_i - to meet the criteria for individual evaluated alternatives, while using the point scale ranging from 1 to 10. This method was designed as the maximisation method [9]. Assigning numerical values to weights and rates of meeting the criteria for individual alternatives was carried out by a group of 3 experts. The resulting order of alternatives was determined on the basis of the largest weighted sum. The results of the decision-making process, while using the DMM method, are shown in **Table 3**.

Table 3 Decision-making table DMM

Criteria	Weights a_i	Finite roller conveyor		Circulating roller conveyor		Combined conveyor	
		u_i	$a_i.u_i$	u_i	$a_i.u_i$	u_i	$a_i.u_i$
K1 - Investments	5	9	45	5	25	7	35
K2 - Power Consumption	9	9	81	6	54	8	72
K3 - Flexibility	8	1	8	7	56	7	56
K4 - Noise Level	7	3	21	7	49	9	63
K5 - Safety	6	3	18	5	30	7	42
Weighted sum		∑ 173		∑ 214		∑ 268	
Order		3.		2.		1.	

The second decision-making method was the Forced Decision Matrix Method (FDMM). The principle of FDMM application is analogical to the DMM. The difference consists solely in assigning individual weights to evaluation criteria by the so-called pairwise comparison. When comparing individual criteria, a more important criterion (more important for a decision) is ranked as "1" and a less important as "0". A similar procedure applies to the pairwise comparison of alternatives. The resulting evaluation of criteria weights and methods is carried out by applying the evaluation "standardisation", i.e. by requesting that the sum of all evaluations, or weights, equals 1. Results of the decision-making process, while applying the FDMM, are shown in **Table 4**.

Table 4 Decision-making table FDMM

Criteria	Weights a_i	Finite roller conveyor		Circulating roller conveyor		Combined conveyor	
		u_i	$a_i.u_i$	u_i	$a_i.u_i$	u_i	$a_i.u_i$
K1 - Investments	0	0.666	0	0	0	0.333	0
K2 - Power Consumption	0.4	0.666	0.2664	0	0	0.333	0.1332
K3 - Flexibility	0.3	0	0	0.5	0.15	0.5	0.15
K4 - Noise Level	0.2	0	0	0.333	0.0666	0.666	0.1332
K5 - Safety	0.1	0	0	0.333	0.0333	0.666	0.0666
Weighted sum		∑ 0.2664		∑ 0.2499		∑ 0.483	
Order		2.		3.		1.	

5. CONCLUSION

The article was dealing with the process of proposing alternative solutions for consignment sorting, while using various handling equipments (conveyors). A decision-making process is based on relevant technical and economic parameters of conveyors. Evaluation criteria were determined for the adjustment of conveyor technical parameters and applicable priorities were specified for conveyor innovation. At the same time, a financial comparison was carried out for the currently applied and the proposed method of consignment handling and an optimal adjustment option was chosen. The results of the application of both multiple-criteria decision-making methods (DMM a FDMM) were identical. Evaluation criteria were best met by a combined conveyor.

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