

Article citation info: Caban, L. – Bokša, P. – Marasová, D., Multi-criteria evaluation of conveyors with a closed conveyor belt. *Transport & Logistics: the International Journal*, 2016; Volume 16, Issue 40, September 2016, ISSN 2406-1069

MULTI-CRITERIA EVALUATION OF CONVEYORS WITH A CLOSED CONVEYOR BELT

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Abstract:

Post address the selection of the most suitable type of conveyor belt fitted with rubber conveyor belt based on the assessment criteria using the two methods of decision analysis. Choosing conveyor is based on the evaluation criteria. Individual values of criteria weights are determined by direct methods for grading scales in groups. Usefulness balance is established by the expert manner and based on the assessment of the technical parameters of conveyors, their advantages and disadvantages as well as areas of their application in practice.

Key words:

Multi-criteria evaluation, closed conveyor, belt

INTRODUCTION

Transport of various materials is a very essential part of the technological processes in all industrial spheres. Currently, the transportation system is considered not only from a technical and economic point of view, but also from the third environmental concerns. This is due to tightening environmental requirements aimed at reducing the adverse impacts of transport material to the environment. Because of this reason there are developed new transport technologies that will jeopardize the environment as least as possible, but simultaneously they are represented by good technical parameters. Transport influence on the environment, from the mining of raw materials until consumption of the end-user, is shown in Fig.1.

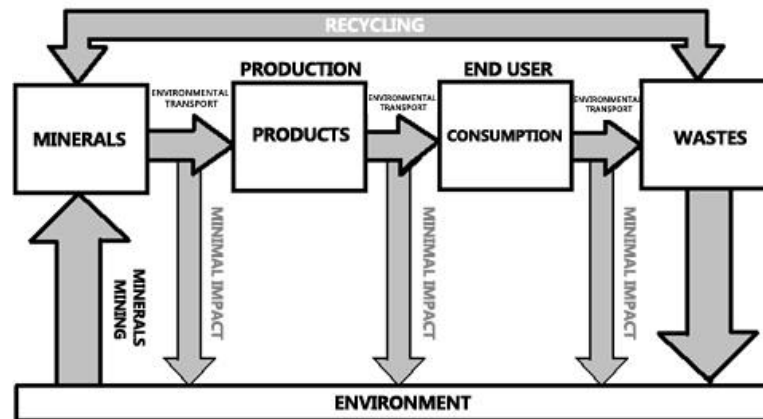


Fig.1 Transport of closed conveyors and its impact on the environment

Reference document published by the European Commission [16] describes the different impacts on the environment. There are especially emissions resulting from the storage and transport of different types of materials. The legal basis of this document refers to environmental protection. To reduce the impact on the environment there are represented special conveyors and systems, which should reduce the negative impact on the environment.

Appropriate solution of materials transport are conveyors with enclosed conveyor belt used for carriage in most cases, loose, granular and lump materials, or piece goods. These conveyors are designed for the purpose of better transport-capacity terms. Compared to conventional conveyors, they bring a number of advantages. Such environmentally friendly and continuously clean transport technologies suitable for transporting material can be included: conveyors fitted with rubber conveyor belt (Tube conveyors, overhead conveyors like Sicon, Becker, Scott, sandwich conveyors and conveyors of U-CON).

Each transport system has its history and its characteristics. Author Johansson, et al is dealing with transportation technology of 1990 in its publications, which include enclosed belt conveyor [7]. The article also points to significant benefits and costs that would be incurred during installation compared to conventional conveyors. History of bulk materials transportation also addresses the article [8]. It describes what has been a fundamental principle of the closed mode of transport. This paper presents the number of completed installation of their capacity.

Tube conveyors are described in detail by authors Fedorko, Molnár, Michalik [2]. A detailed description of the special conveyor for steep and vertical transport is outlined in the monograph of Hrabovský [3]. Rollers and roller stools are part of each conveyor belt devices. The various versions of these devices can be find just in catalog of company Transroll.[4] The issue of the continuous transport of bulk and lump materials were processed by the team of authors in The Belt Transport publication [5], where one chapter describes special versions of conveyor belts having enclosed conveyor belt. In the document [10], the authors devote a special closed delivery system. The article is focused on introducing systems with enclosed conveyor belt and to highlight the correct choice of transport equipment for a given application. In the paper Lukac [11] is addressing the replacement of classical conveyor belt to tube one running in Nižná Šlaná and experience of its deployment of praženec transport. Bahke [12] addresses the criteria calculation and the application of a special type of tube conveyor Rollgurt. He is also pointed out the benefits. Santos in the paper [13] addresses the issue of costs sandwich system. Like their history and evolution. Tingskog [14], describes this special system in his article. It emphasizes free choice of routes, high safety, low investment costs and low maintenance costs.

1 OVERVIEW OF TUBE CONVEYOR INSTALL IN INDUSTRY

In the world, there are a lot of manufacturers of conveyors with enclosed conveyor belt. Slovakia and the Czech Republic also are no exception. Many pipe conveyor installations were realized by Schenck - TEDO and BeumerGroup [10]. Based on the information of those companies each installation pipe conveyor was analyzed. Fig. 2 provides an overview of these facilities in 1994 - 2013. These companies made the largest number of installations in the Czech Republic 67%. Slovak Republic participates complete the installation of 19%. Poland, Serbia, Romania, Bosnia and France had the lowest number of installations during the reporting period.

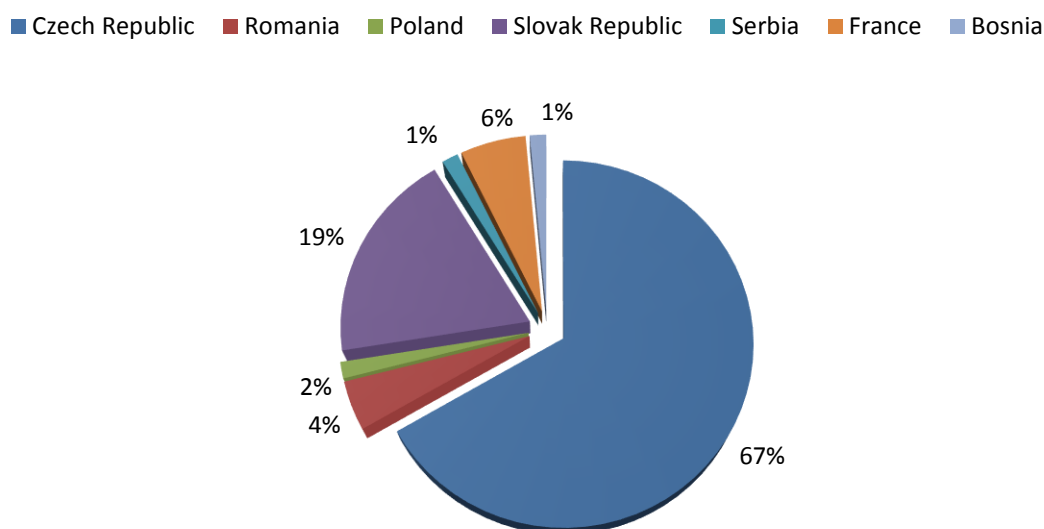


Fig. 2 Overview of tube conveyor installation

Fig. 3 shows an overview of the materials in those installations. The most transported are ash and dross, which is 40% of the total number of installations. Alternative fuels are the kinds of materials that are transported to the value of 17%. The following is limestone with 15% of transported cases. Coal dust, cement, gypsum, sludge, sand and fertilizer are transported with the smallest share in these installations.

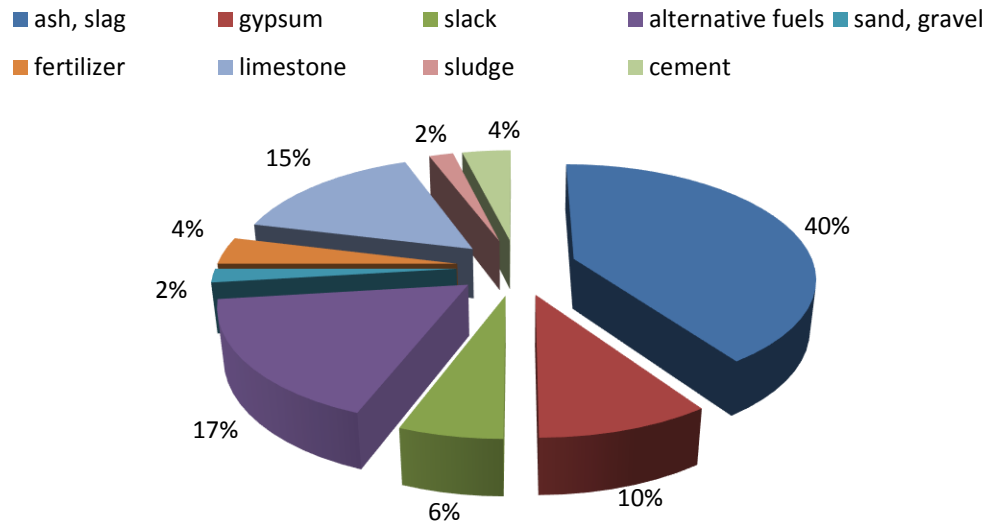


Fig. 3 Overview of transported materials for the installation

On the basis of transported materials is clear, there was the most installations in the building industry, 61%. The energy industry represents 36% of total installed devices. The lowest position has chemical industry, only 3% (Fig. 4).

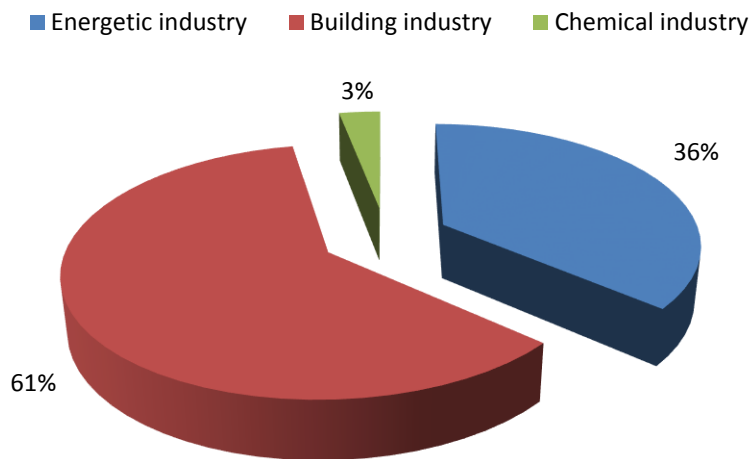


Fig. 4 Overview of tube conveyor installations in the industry

2 CHARACTERISTICS OF CLOSED BELT CONVEYOR

These are the conveyors of special design and construction. The biggest and most important difference of these devices is a conveyor belt. Most were made in order to transport loose and dusty materials. These conveyors can be installed in almost all industries.

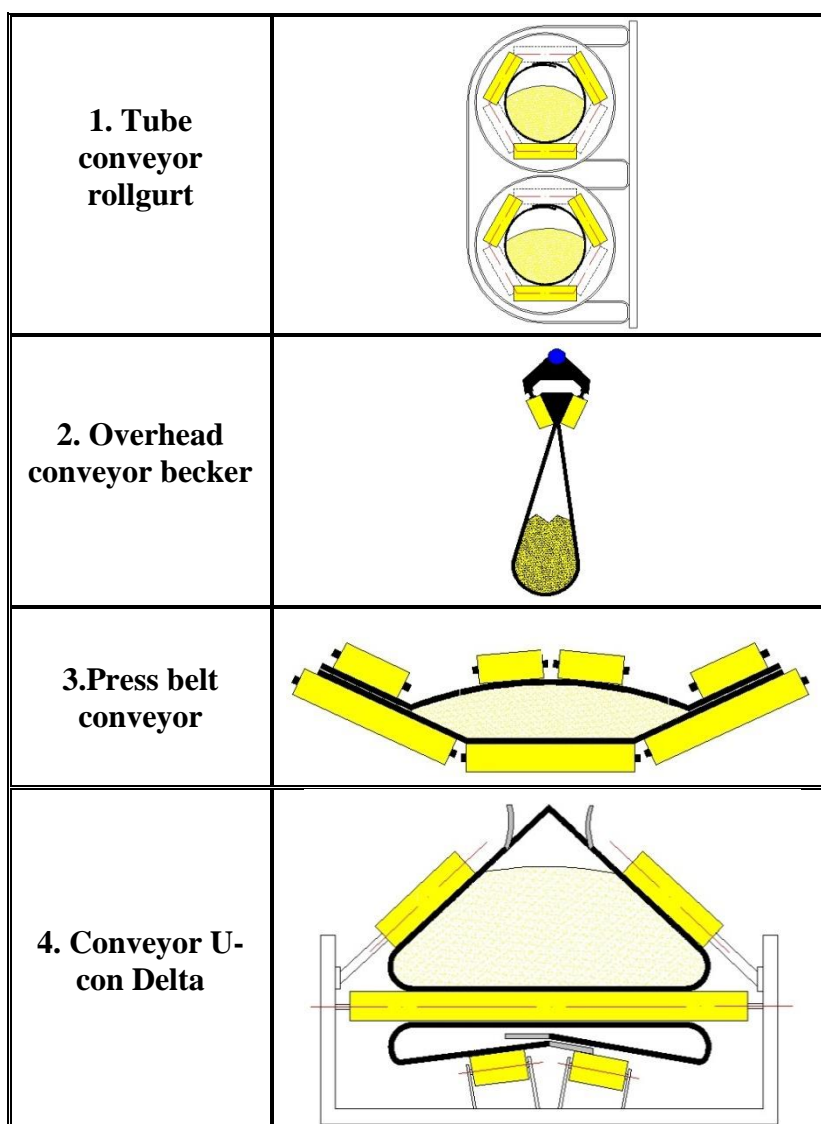


Fig. 5 Scheme of chosen conveyor with closed belt

1. Tube conveyors

Tube conveyors supporting structures (Fig. 5) are placed on the ground or on supports, if necessary, to overcome terrain obstacles or buildings. They are used especially when the transport of material causes the environmental pollution. Its advantage is to protect transported material from degradation in pipelines. Conveyor allows overcome horizontal and vertical arcs. It can overcome the climb up to 30°. In the carriage there is no material packing rollers and its great advantage is the possibility to transport the upper and lower branches on a very long distance. [1]

Technically, the disadvantage is less transport capacity compared to conventional conveyors and greater physical resistance because of a plurality of rotating rollers to maintain the desired closed circular profile. Its disadvantages can be ranked even higher investment costs and restrictions on the transport of large particulate materials. [2]

2. Overhead conveyors

Conveyors are hinged to the bearing structures. They are different by the way of support structure leading and other structural elements. There are several commercial systems such as SICON, EnerkaBecker, Scott.

The main advantage of SICON (Fig. 6) is elimination of dunes thanks to ability to copy terrain well. It does not pollute the environment because while reflux, conveyor belt is closed, it protects material from the weather and enables bi-directional transport of material. The structure is light and flexible. Space requirements are minimal. It allows the movement at 35° angle of inclination. It is characterized by overcoming sharp bends. A significant reduction in maintenance costs, high-capacity and low physical resistance make this system widely used in practice. The disadvantage of this device is that it cannot carry particulate material. [4]

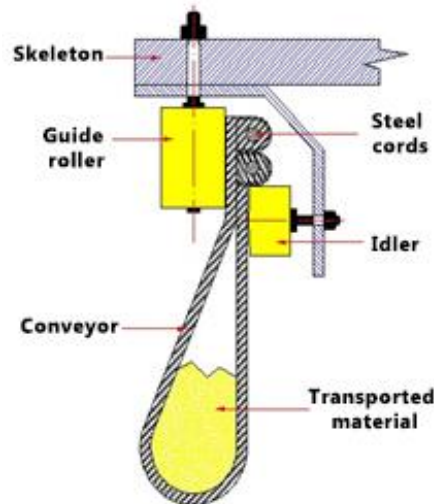


Fig.6 Scheme of overhead conveyor Sicon

Enerka Becker system (Fig. 5) is characterized by particularly simple and lightweight construction, which means considerable savings in terms of investment. Length of construction is almost unlimited. Multipoint drive provides low voltage at the waist, and thus longer life. The construction of the conveyor enables two-way traffic. All parts of the device are easy to control and require low maintenance. Transported material remains inside and manages protection of the material, air, and the protection of the moving parts of the device. It allows flexible management track, transport of climbing at an angle up to 35° . This system can transport different types of materials, dangerous, sticky, precious metals and fine materials. The conveyor as well as Sicon is not designed to transport large pieces of material. [5]

Scott system is distinguished by even better shipping capacity characteristics as Sicon conveyors and EnerkaBecker. Its great advantage is the leading angle of up to 80° , due to the special construction of the conveyor belt. Its simple modular design means faster installation and removal. A conveyor belt is also made up of individual pieces which are mutually assembled and disassembled easily and to facilitate its exchange. There is no leaking material during the transport. The advantage is that it can transport high piece material. In this way, the system can be in both arms. The construction doesn't need to be fixed, but may be flexible on the wheel and ensuring the transport of the mobile material. As can be understood, disadvantage is just smaller carrying capacity compared to the pipe conveyor. [9]

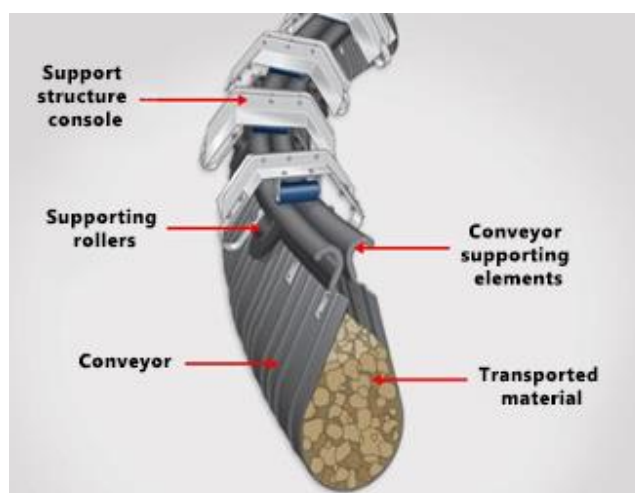


Fig. 7 Schema of overhead conveyor Sicon type [9]

3. Press belt conveyors

Principle of the sandwich conveyor special design (Fig. 5) is the upper and lower conveyor belt which provide a closed transport materials to the inclination of 90 °. At different angles inclines there is no change in transmission capacity. It can transport wet material, and thus replace the bucket elevators. A disadvantage of the sandwich conveyor belt cover is many times greater design complexity, increased wear of the conveyor belt and higher energy consumption compared to conventional conveyors. A further disadvantage is that these systems cannot produce horizontal curvature. [3]

4. System U-CON

Introducing of closed system U-CON (Fig. 5) has opened up new opportunities for creating economic material transport over long distances and high altitude differences. The main element of U-CON's patented closed belt. The system uses fewer rollers as compared to the pipe conveyor, thereby locking system. The first very important feature is the high level of safety with the optimal tension of the conveyor belt and minimizing the number of rotating parts. The second feature of this system is low maintenance costs. Easy replacement of rollers repairs associated with the operation and low power consumption are significant factors that characterize the system U-CON. There are different types of system, such as a U-CON QL, DELTA U-CON. [6] [3]

3 CHOOSING THE RIGHT TYPE OF CONVEYORS BY USING MULTI-CRITERIA EVALUATION

Multi-criteria decision making is a suitable tool for the selection of suitable alternatives and the occurrence of various evaluation criteria. Straka points to a number of methods that can be used in various calculations in logistics [15]. One of the methods for analyzing decision problems using a hierarchical structure is the method of AHP (Analytic Hierarchy Process). Andrejiová et al (2013) has used the AHP method at the determination of the optimal selection criteria of conveyor belts and she has defined the weight of main criteria important for the selection of conveyor belts from the technical, energy, economic, ecological and ergonomic aspect (Andrejiová et al, 2012).

In choosing the most suitable conveyor with a closed conveyor belt was applied a multi-criteria approach, using two multi-criteria methods, proportionately index method and Metfessell allocation. Conveyors were assessed by three experts and the tasks were designed as maximization. Using proportionately index method, it's possible to determine the optimal

conveyor type based on criteria. Individual values of criteria weights are determined by direct methods for grading scales in groups. The weights are assigned to the criteria as follows (Tab. 2): a group of very important criteria - 6, a group of medium significance criteria - 4, a group of a few important criteria - 2. Partial utility is designed by direct access [1,3]: 1 - does not satisfies criteria 3 - satisfies criteria (Tab. 3). [9]

Tab. 2. Allocation of weights and their transfer to standard value

<u>Criteria</u>	NONSTANDARD VALUE w_i	STANDARD VALUE α_i
<u>Dustless transport</u>	4	4/38 = 0,11
<u>Flexibility</u>	4	4/38 = 0,11
<u>Rapid horizontal curvature</u>	6	6/38 = 0,16
<u>Vertical climb > 45°</u>	6	6/38 = 0,16
<u>Capacity > 1900 t.h⁻¹</u>	4	4/38 = 0,11
<u>Transport distance ≥ 5 km</u>	4	4/38 = 0,11
<u>Easy belt instalation</u>	4	4/38 = 0,11
<u>Variable structure</u>	6	6/38 = 0,16
<u>Both arms transport</u>	6	6/38 = 0,16
Sum	38	1

Tab. 3. The classification of individual conveyors types

CRITERIA	α_i	PIPE		SICON		ENERKA BECKER		SCOTT		SANDWICH		U-CON QL	
DUSTLESS TRANSPORT	0,11	3	0,33	3	0,33	3	0,33	3	0,33	1	0,33	3	0,33
FLEXIBILITY	0,11	3	0,33	3	0,33	3	0,33	3	0,33	1	0,33	3	0,33
RAPID HORIZONTAL CURVATURE	0,16	1	0,16	3	0,48	3	0,48	3	0,48	1	0,16	1	0,16
VERTICAL CLIMB > 45°	0,16	1	0,16	1	0,16	1	0,16	3	0,48	3	0,48	3	0,48
TRANSPORT CAPACITY > 1900 t.h ⁻¹	0,11	3	0,33	1	0,11	1	0,11	1	0,11	1	0,11	1	0,11
TRANSPORT DISTANCE ≥ 5 km	0,11	3	0,33	3	0,33	3	0,33	3	0,33	1	0,11	1	0,11
EASY BELT INSTALATION	0,11	1	0,11	1	0,11	1	0,11	3	0,33	1	0,11	1	0,11
VARIABLE STRUCTURE	0,04	3	0,12	1	0,04	1	0,04	3	0,12	1	0,04	1	0,04
BOTH ARMS TRANSPORT	0,16	3	0,48	3	0,48	3	0,48	3	0,48	1	0,16	3	0,48
SUM	1		2,35		2,37		2,37		2,99		1,83		2,26
ORDER			3.		2.		2.		1.		5.		4.

Optimal conveyor using the method is Scott, who has earned the highest rating.

The process of conveyors type comparison is made through methods multiplier awards for the appropriateness of the results. Value of criteria weights shall be determined by Metfessell allocation. The essence of this method is assigning weights to the criteria to totals 100 (Tab. 4). Among the various criteria are divided 100 points are divided between various criteria with result of more sensitive criteria assessment. [15] Table 4 shows the conversion of non-standardized to the standardization value of the instrument. Partial utility is designed by direct access [1,3]: 1 - does not satisfy criteria 3 – satisfies criteria. In Table 5, there is the assessment of individual conveyors by normalizing the scales evaluation value.

Tab. 4. Allocation of weights and their transfer to standard value

CRITERIA	NONSTANDARD VALUE w_i	STANDARD VALUE a_i
Dustless transport	12	12/100 = 0,12
Flexibility	10	10/100 = 0,1
Rapid horizontal curvature	14	14/100 = 0,14
Vertical climb > 45°	15	15/100 = 0,15
Capacity > 1900 t.h ⁻¹	8	8/100 = 0,08
Transport distance ≥ 5 km	5	5/100 = 0,05
Easy belt installation	11	11/100 = 0,11
Variable structure	7	7/100 = 0,07
Both arms transport	18	18/100 = 0,18
Sum	100	1

Tab. 5. The classification of individual conveyors types

CRITERIA	a_i	PIPE		SICON		ENERKA BECKER		SCOTT		SANDWICH		U-CON QL	
DUSTLESS TRANSPORT	0,12	3	0,36	3	0,36	3	0,36	3	0,36	1	0,12	3	0,36
FLEXIBILITY	0,1	3	0,3	3	0,3	3	0,3	3	0,3	1	0,1	3	0,3
RAPID HORIZONTAL CURVATURE	0,14	1	0,14	3	0,42	3	0,42	3	0,42	1	0,14	1	0,14
VERTICAL CLIMB > 45°	0,15	1	0,15	1	0,15	1	0,15	3	0,45	3	0,45	3	0,45
TRANSPORT CAPACITY > 1900 t.h ⁻¹	0,08	3	0,24	1	0,08	1	0,08	1	0,08	1	0,08	1	0,08
TRANSPORT DISTANCE ≥ 5 km	0,05	3	0,15	3	0,15	3	0,15	3	0,15	1	0,05	1	0,05
EASY BELT INSTALATION	0,11	1	0,11	1	0,11	1	0,11	3	0,33	1	0,11	1	0,11
VARIABLE STRUCTURE	0,07	3	0,21	1	0,07	1	0,07	3	0,21	1	0,07	1	0,07
BOTH ARMS TRANSPORT	0,18	3	0,54	3	0,54	3	0,54	3	0,54	1	0,18	3	0,54
SUM	1	1,02 ⁻⁶		3,39.10 ⁻⁷		3,39.10 ⁻⁷		9,16.10 ⁻⁶		4,19.10 ⁻⁹		1,13.10 ⁻⁷	
ORDER		2.		3.		3.		1.		5.		4.	

4 CONCLUSION

Result of the calculation through the method of proportional index is almost identical to the result of the calculation methods of multiplication valuation. The difference is in close proximity of the benchmarking system Sicon, Enerka Becker and pipe conveyor. These overhead conveyors have the same rating for both methods. When using rate-index method worked, the better devices with minimal differences are overhead conveyors. In the second method of multiplying the valuation lead pipe conveyor. For other types the order didn't change.

A sandwich conveyor is the least satisfactory. The machine cannot transport material in both arms and it also leaks during transportation. Its structural complexity is big disadvantage. Flexibility is another of his weaknesses. It can carry almost all kinds of loose and dusty materials. This system is intended for short and steep transport to the angle of inclination of 90°.

Under the current criteria, optimal conveyor is a special overhead conveyor Scott, thanks to their transport-capacity characteristics. This device differs from the overhead conveyor that is able to transport the material with sharp vertical rise up to 80 °. Also, its simple modular design allows easy assembly and disassembly as well as flexibility. The advantage is the possibility of variable transport material. Everything is based on specially formulated conveyor belt that allows the blade horizontal curvature. It is capable of transporting bulk and larger pieces of material without leakage. Simplified installation and transportation in both arms contribute to the versatility. Its carrying capacity is comparable to other overhead conveyor.

Acknowledgement

This article is the result of the Project implementation: University Science Park TECHNICOM for Innovation Applications Supported by Knowledge Technology, ITMS: 26220220182, supported by the Research & Development Operational Programme funded by the ERDF. "We support research activities in Slovakia/This project is being co-financed by the European Union", Thiswork is a part of these project KEGA 009TUKÉ-4/2016 - Design of the specialized training concept oriented to the development of experimental skills within the frame of education in the study branch logistics.

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