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POSSIBILITIES FOR REDUCING THE NEGATIVE IMPACT OF THE NUMBER OF CONVEYORS IN A COAL TRANSPORTATION SYSTEM

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Subject review

Belt conveyors are usually applied in coal conveyance, whether the reference is made to conveyance in mines themselves or from mines to the nearest consumers. These conveyance systems have often a large number of transporting units, which may have a negative impact on the system reliability and the environment. This paper deals with the possibilities for reducing the number of conveyors in a coal conveyance system by maximizing the conveyor length and the possibility of applying horizontal bend conveyors.

Key words: *negative impact, number of conveyors, reducing, transportation system*

Mogućnosti za smanjenje negativnog utjecaja broja transportera u sustavu transporta ugljena

Pregledni članak

Trakasti transporteri se obično primjenjuju u transportu ugljena, bilo da se koristi u rudnicima ili od rudnika do najbližeg potrošača. Ovi sustavi transporta često imaju veliki broj transportnih jedinica, što može imati negativan utjecaj na pouzdanost sustava i okoliš. U ovom radu se razmatraju mogućnosti za smanjenje broja transportera u sustavu transporta ugljena, povećavanjem duljine transportera i uz mogućnost primjene horizontalnih lukova transportera.

Ključne riječi: *broj transportera, negativni utjecaj, smanjenje, transportni sustav*

1 Introduction
Uvod

The prevailing method of conveyance in coal mines, both in underground and open-cast mining, is belt conveyor system. In addition to an indisputably large number of advantages, belt conveyors have also some shortcomings, which are reflected, among others, in the existence of a large number of units in the system.

Lengths of belt conveyors in coal mines range from few tens to few thousand meters. At points where conveyors are connected into the system, a number of problems occur – such as the necessity for an automated loading/unloading, successive start-up operation, maintenance of power stations and negative environmental impact. Many researchers proved that the reliability of a multi-conveyor system is lower compared to the reliability when this number is minimal.

The aim of this paper is to analyse the possibilities for reducing the number of conveyors in a system, through maximum increase of the conveyor length, depending on the characteristics of a belt as a bearing and haulage apparatus. The aim is also to discuss possibilities for reducing the number of units by applying horizontal bend conveyors. The results of these researches arose from the team work of relevant departments of BERG Faculty, Technical University Košice (Slovakia) and the Faculty of Mining and Geology, University of Belgrade (Serbia).

2 Some parameters of the negative impact of the number of conveyors in the system
Neki parametri negativnog utjecaja broja transportera u sustavu

Continuous transportation systems are composed of numerous elements and their reliability depends upon the number of these elements and also on the reliability of each particular element. Coal transportation systems may, in some cases, comprise more than 10 elements and their overall reliability is less than 50 % of the minimum reliabillity of each particular conveyor.

The large number of conveyors within the coal transportation system also has a significantly unfavorable bearing on the environment. It is recorded that considerable air pollution, soil degradation etc. occurs at transfer points. This problem is particularly pronounced during the transportation of coal fines from the mine to the coal-fired power plants.

The transportation of coal from the mine toward primary consumers (coal-fired power plants, separation plants etc.) is usually developed through transportation systems that consist of several belt conveyors. If one of the reliability parameters of the *i*-th element of the system is indicated as r_i, then the reliability of the system will be as follows:

$$r = \prod_{i=1}^{m} r_i . \tag{1}$$

Here *m* represents the number of conveyors in the system.

The coefficient of time efficiency and the coefficient of readiness may be considered as the most comprehensive indicators of reliability during coal transportation by belt conveyors. If one transportation system is composed of *m* conveyors of equal or approximately equal reliability (ideal case), then the overall reliability of the system will be:

$$r = r_i^m . \tag{2}$$

The diagram (Fig. 1) shows how the reliability of the transportation system changes with the increase in the number of conveyors and spare elements within the system.

The parameters of reliability also affect the efficiency of transmission within the transportation system. Receiving ability of the transportation system, with directly connected conveyors, depends upon the minimum capacity of a conveyor within the system Q_{min} and the parameter k_{br}:

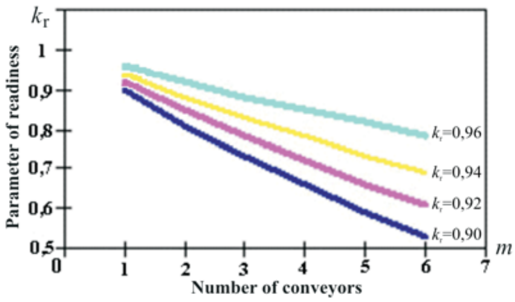

***Figure 1** Dependence of the coefficient of readiness on the number of elements in the transportation system for different parameters of readiness k_r (0,96; 0,94; 0,92 and 0,90)*

***Slika 1.** Ovisnost koeficijenta spremnosti o broju elemenata u transportnom sustavu za različite parametre spremnosti k_r (0,96; 0,94; 0,92 i 0,90)*

$$P_{\mathrm{rs}} = Q_{\min} \prod_{i=1}^{m} k_{\mathrm{br}i}. \tag{3}$$

Time efficiency ratio k_{b} is one of the most important parameters to determine the reliability of haulage systems. It represents the ratio of the aggregate duration of all the periods of uninterrupted work to the duration of all the standstills for the time observed t. The most precise results are obtained with the so-called calculation time efficiency ratio (k_{br}), which also introduces k_{b} (time efficiency ratio of haulage systems) and the machine time ratio k_{m} (which represents the ratio of the aggregate duration of periods of uninterrupted work to the time t).

$$k_{\mathrm{br}} = \frac{k_{\mathrm{m}}}{1 - k_{\mathrm{b}} + k_{\mathrm{m}}}.$$

Introducing the parameter of probability to achieve the value of supposed uneven arrival of coal on a conveyance system z and creating a ratio between the receiving ability and the mean (expected) value of coal inflow to the transportation system $M(q)$. Computing receiving ability may be determined through the following expression:

$$P_{\mathrm{rs}} = M(q) \cdot k_{\mathrm{br}} \cdot (1 + z \cdot k_{\mathrm{if}}), \tag{4}$$

where:
k_{if} – the factor of coal inflow fluctuation in observed period t
q – intensity of coal flow on a conveyance system.

The adverse impact of multi-conveyor system for external coal transportation is pronounced mainly at transfer points. The detrimental effects are most frequently recorded at conveyor junction points, and they may be as follows:

- soil degradation due to installation of drive stations and transfer units,
- occupation of areas for the construction of power units and other facilities intended for supply of drive stations,
- increased dust concentration at coal transfer points caused by coal dust,
- high noise level at terminal stations etc.

Coal transportation systems intersect different environments, from protected natural environments to residential areas. The level of detrimental impact on the environment varies and depends on numerous factors.

Soil degradation and occupation of useful areas in well protected and highly preserved natural surroundings may affect the environment to a certain extent, although this impact generally has no major significance. The same is with the rise of noise at drive stations, which is not substantial considering the entire conveyor route.

Major harmful impacts of multi-conveyor systems appear due to increased dust concentration at transfer points. The level of dust concentration depends on the following factors:

- content of fine fractions in coal to be transported,
- humidity level of material,
- climatic conditions (humidity in air, intensity of air streams, air temperature etc.),
- conveyor belt speed,
- surface of contact areas between load and air, etc.

3 Defining maximum lengths of conveyors in coal conveyance
Definiranje maksimalne duljine transportera u transportu ugljena

Many research workers were dealing with the issue of maximum lengths of belt conveyors in coal mines. We are all familiar with the methods developed in Poland [1,12] and in Russia [2], etc. However, each of these methods has certain limitations that negatively influence their general purpose.

At the Faculty of Mining and Geology in Belgrade [3, 4] a formula has been developed which also introduces the coefficient of safety K_{S} and the factor of reserve, to avoid sliding under on the drive drum K_{t}:

$$L_{\max} = \frac{B \cdot n \cdot \sigma_{\mathrm{k}}}{K_{\mathrm{S}} \cdot (X \cdot w \cdot \cos\beta \pm Y \cdot \sin\beta)}, \tag{5}$$

where:

$$X = 1{,}21 \cdot K_{\mathrm{t}} \cdot \frac{q_{\mathrm{k}} + 2q_{\mathrm{t}} + q_{\mathrm{o}} + q_{\mathrm{p}}}{\mathrm{e}^{\mu \cdot \alpha} - 1} +$$
$$+ (1{,}1 \cdot K_{\mathrm{t}} + 1) \cdot (q_{\mathrm{t}} + q_{\mathrm{p}}) + q_{\mathrm{k}},$$

$$Y = q_{\mathrm{k}} \cdot \left(\frac{1{,}21 \cdot K_{\mathrm{t}}}{\mathrm{e}^{\mu \cdot \alpha} - 1} + 1 \right) - 0{,}1 \cdot q_{\mathrm{t}}.$$

In the above formula, B indicates the belt width, n – the number of belt gussets, σ_{k} – tensile strength of one gusset, w – factor of the resistance to belt movement, β – conveyor slope, q_{k} – mass of the useful load on a belt, q_{t} – mass of one meter of the belt, q_{o} and q_{p} - resistances to reaction of rollers from the loaded and reverse side, μ – factor of friction between a belt and drive drum, α – comprehensive angle of the belt around the drive drum.

Apart from these formulae, there is a number of procedures to determine limit lengths for the application of conveying belts. Each of them has some shortcomings, because it does not comprise all the parameters defining the belt length. Therefore the so-called indirect method has been applied. This method, starting from some conveyor lengths, defines the other elements, taking as the relevant parameter the degree of belt safety. By changing the conveyor lengths we arrive at certain dependences determining the procedure of computing limit lengths.

This methodology requires a great number of calculations which is impossible to carry out in a reasonable time without application of computer programmes. For simple calculation, the corresponding programme has comprised three matrices into its database:

- The maximum capacity matrix $\boldsymbol{Q}_{i,j}$, which represents maximum capacities of belt conveyors for determined widths and speed of a belt.
- The matrix of conveyor movable parts $\boldsymbol{G}_{i,j}$

$$\boldsymbol{G}_{\boldsymbol{i},\boldsymbol{j}} = 3{,}6 \cdot v \cdot (q_\mathrm{o} + 2q_\mathrm{t} + q_\mathrm{p}). \tag{6}$$

- The safety matrix

$$\boldsymbol{S}_{\boldsymbol{i},\boldsymbol{j}} = \frac{n \cdot \sigma_\mathrm{k} \cdot B \cdot v}{100}. \tag{7}$$

In the above formula, n indicates the number of belt gussets, and v the belt speed.

All matrices are two-dimensional, with 120 elements, classified by i and j. Where: $i = 1,2,\ldots,8$, and $j = 1,2,\ldots,15$. Each of the elements given in the formulas (6) and (7) has also its values classified by i and j.

By this procedure a calculation of maximum lengths of the coal belt conveyors has been carried out. Tab. 1 gives the values of limit lengths in meters, obtained by the indirect method L_0 and the values of lengths L_1, the values of which are obtained using the methodology of Russian researchers [2, 9], for horizontal transportation routes. The width B is given in mm, σ_k in N/cm, and the velocity v in m/s. The table shows considerable differences between the two given procedures, which is logical since the indirect method comprises a number of parameters. In both cases we deal with the maximum belt capacity. In case smaller amounts of coal Q_h1 are to be conveyed, the correction of lengths should be done by means of the following formula:

$$L_\mathrm{k} = C_\mathrm{k} \cdot L = \left(\frac{Q_\mathrm{h}}{Q_\mathrm{hl}} - \frac{1}{0{,}15 \cdot L} \right) \cdot L, \tag{8}$$

where L_k is the corrected conveyor length in meters.

If we use a multi-drive conveyor with overall belt approach angles around drive drums are α_1, the corrected conveyor length would be as it is shown in Tab. 1.

$$L_1 = 1{,}54 \cdot L \cdot \frac{\mathrm{e}^{\mu \cdot \alpha_1} - 1}{\mathrm{e}^{\mu \cdot \alpha_1}}. \tag{9}$$

In this way, by the indirect method, we obtain values of limit lengths for inclined conveyors, too. Regularities of application and analytical expressions for obtaining maximum lengths for the belts set in slanting workings have been determined. The corresponding diagrams for approximate determination of belt conveyor lengths have also been made.

4 Reducing the number of conveyors by introducing horizontal bend conveyors

Smanjenje broja transportera uvođenjem horizontalnih krivina transportera

A large number of conveyors in a system is often the consequence of broken routes, which results from the need to by-pass obstacles on the road or the limitations arose from constructed underground galleries.

All over the world, and especially in the last 30 years, there are tens of horizontal curve belt conveyors installed. Their capacity amounts from a few hundreds to thousands of tons per hour. There are no special constructive sub-assemblies and parts; simple belts with plies of fabric or steel ropes are used. There are no additional expenses for manufacturing new parts and facilities, in relation to ordinary conveyors in straight-line routes.

The main idea for installing conveyors in curve resulted from the fact that belt tensioning in the curve makes components of the horizontal forces which act towards the interior part and the center of the curve. The value of these forces depends on the following factors:

- Initial belt tension;
- Belt stretching forces in particular working conditions;
- Horizontal curve radius;
- Distance between support rollers.

With some approximations, the value of the force acting in some point in the curve may be defined through the following equation [10]:

$$F_x = T \cdot \frac{R_\mathrm{c}}{R_\mathrm{c}^2 - \left(x - \frac{L_\mathrm{c}}{2} \right)^2}, \tag{10}$$

where:
R_c – horizontal curve radius, m
L_c – curve length, m
x – distance of the observed point from the beginning of the curve, m
T – actual tension of the belt at the distance x, N.

In order to enable the movement, in spite of radial forces towards the centre of the curve, the balance should be established by introducing countervail forces. This may be carried out by placing rollers at specified angle and by uplifting the inner edge of the belt. This leads to the compensation and creates components which are directed from the centre of the curve.

Tensioning forces of the belt, especially at big distances, are variable, depending on the values of distributed and concentrated resistances along the track. Since the elastic properties of the belt play a large role in placing belts in horizontal curves, first it is necessary to anticipate all possible changes of tensioning forces in each part of the track. Also it is necessary to estimate properly the influence of curves, at vertical level, on the mechanical properties of the belt, in order to anticipate its behaviour in the curve. Several large design companies in the USA and in Germany dealing with these issues have complex simulation models for determining the behaviour of the belts in horizontal curves.

Table 1 *Dependence of the length of belt conveyor on technical parameters*
Tablica 1. *Ovisnost duljine remena transportera o tehničkim parametrima*

	1	2	3	4	5	6	7	8
1	B=800 n=3 σ_k=1600 v=1,31 L_0=750 L_1=1320	B=800 n=3 σ_k=2000 v=1,31 L_0=1000 L_1=1650	B=800 n=3 σ_k=2500 v=1,31 L_0=1350 L_1=2070	B=800 n=3 σ_k=3150 v=1,31 L_0=1750 L_1=2600	B=800 n=3 σ_k=4000 v=1,31 L_0=2050 L_1=3310	B=1000 n=3 σ_k=1600 v=1,31 L_0=550 L_1=980	B=1000 n=3 σ_k=2000 v=1,31 L_0=800 L_1=1230	B=1000 n=3 σ_k=2500 v=1,31 L_0=1100 L_1=1530
2	B=800 n=3 σ_k=1600 v=1,68 L_0=750 L_1=1320	B=800 n=3 σ_k=2000 v=1,68 L_0=1050 L_1=1640	B=800 n=3 σ_k=2500 v=1,68 L_0=1400 L_1=2060	B=800 n=3 σ_k=3150 v=1,68 L_0=1750 L_1=2590	B=800 n=3 σ_k=4000 v=1,68 L_0=2050 L_1=3290	B=1000 n=3 σ_k=1600 v=1,68 L_0=550 L_1=990	B=1000 n=3 σ_k=2000 v=1,68 L_0=800 L_1=1230	B=1000 n=3 σ_k=2500 v=1,68 L_0=1100 L_1=1540
3	B=800 n=4 σ_k=1600 v=1,31 L_0=1050 L_1=1770	B=800 n=4 σ_k=2000 v=1,31 L_0=1450 L_1=2210	B=800 n=4 σ_k=2500 v=1,31 L_0=1800 L_1=2760	B=800 n=4 σ_k=3150 v=1,31 L_0=2100 L_1=3480	B=800 n=4 σ_k=4000 v=1,31 L_0=2400 L_1=4420	B=1000 n=4 σ_k=1600 v=1,31 L_0=850 L_1=1310	B=1000 n=4 σ_k=2000 v=1,31 L_0=1150 L_1=2050	B=1000 n=4 σ_k=2500 v=1,31 L_0=1500 L_1=2050
4	B=800 n=4 σ_k=1600 v=1,68 L_0=1100 L_1=1750	B=800 n=4 σ_k=2000 v=1,68 L_0=1450 L_1=2190	B=800 n=4 σ_k=2500 v=1,68 L_0=1800 L_1=2740	B=800 n=4 σ_k=3150 v=1,68 L_0=2100 L_1=3450	B=800 n=4 σ_k=4000 v=1,68 L_0=2400 L_1=4390	B=1000 n=4 σ_k=1600 v=1,68 L_0=850 L_1=1320	B=1000 n=4 σ_k=2000 v=1,68 L_0=1150 L_1=1640	B=1000 n=4 σ_k=2500 v=1,68 L_0=1500 L_1=2060
5	B =800 n=5 σ_k=1600 v=1,31 L_0=1400 L_1=2210	B =800 n=5 σ_k=2000 v=1,31 L_0=1850 L_1=2760	B=800 n=5 σ_k=2500 v=1,31 L_0=2050 L_1=3450	B=800 n=5 σ_k=3150 v=1,31 L_0=2350 L_1=4350	B=800 n=5 σ_k=4000 v=1,31 L_0=2650 L_1=5520	B=1000 n=5 σ_k=1600 v=1,31 L_0=1150 L_1=1640	B=1000 n=5 σ_k=2000 v=1,31 L_0=1500 L_1=2050	B=1000 n=5 σ_k=2500 v=1,31 L_0=1850 L_1=2560
6	B=800 n=5 σ_k=1600 v=1.68 L_0=1400 L_1=2190	B=800 n=5 σ_k=2000 v=1.68 L_0=1750 L_1=2740	B=800 n=5 σ_k=2500 v=1.68 L_0=2050 L_1=3430	B=800 n=5 σ_k=3150 v=1.68 L_0=2350 L_1=4320	B=800 n=5 σ_k=4000 v=1.68 L_0=2650 L_1=5490	B=1000 n=5 σ_k=1600 v=1.68 L_0=1150 L_1=1650	B=1000 n=5 σ_k=2000 v=1.68 L_0=1500 L_1=2060	B=1000 n=5 σ_k=2500 v=1.68 L_0=1850 L_1=2570
7	B=800 n=6 σ_k=1600 v=1,31 L_0=1650 L_1=2650	B=800 n=6 σ_k=2000 v=1,31 L_0=2000 L_1=3320	B=800 n=6 σ_k=2500 v=1,31 L_0=2250 L_1=4240	B=800 n=6 σ_k=3150 v=1,31 L_0=2550 L_1=5220	B=800 n=6 σ_k=4000 v=1,31 L_0=2850 L_1=6630	B=1000 n=6 σ_k=1600 v=1,31 L_0=1400 L_1=1970	B=1000 n=6 σ_k=2000 v=1,31 L_0=1750 L_1=2460	B=1000 n=6 σ_k=2500 v=1,31 L_0=2050 L_1=3070
8	B=800 n=6 σ_k=1600 v=1,68 L_0=1700 L_1=2630	B=800 n=6 σ_k=2000 v=1,68 L_0=2000 L_1=3290	B=800 n=6 σ_k=2500 v=1,68 L_0=2300 L_1=4110	B=800 n=6 σ_k=3150 v=1,68 L_0=2550 L_1=5780	B=800 n=6 σ_k=4000 v=1,68 L_0=2800 L_1=6580	B=1000 n=6 σ_k=1600 v=1,68 L_0=1400 L_1=1970	B=1000 n=6 σ_k=2000 v=1,68 L_0=1800 L_1=2470	B=1000 n=6 σ_k=2500 v=1,68 L_0=2050 L_1=3080

Economic justifiability of introducing a system may be estimated by means of the justifiability factor:

$$c = \frac{T_s + T_r}{T_{s1} + T_{r1} + T_{zs}}, \tag{11}$$

where:
T_s and T_r – annual operating costs of the horizontal curves conveyor,
T_{s1} and T_{r1} – annual operating costs of the multi-conveyor system,
T_{zs} – costs resulted from the measures for environmental protection in reloading points.

In normal market conditions the economic justifiability of introducing a single-belt system in the horizontal curve amounts from 0,6 to 0,8, which shows the advantages of this haulage system of tailings (refuse ore) and useful ore outside the borders of the open-pit mine.

To install curvilinear belt conveyors in conditions of underground mining, to begin with, it is necessary to carry out certain mining operations in order to adjust the crossings or deviations to the construction of the curvature (Fig. 2). The scope of these operations depends on the length of the curve arc and on the deviation angle θ.

The level of investments for the installation of one curvature may be determined applying the following expression:

Table 1 *Dependence of the length of belt conveyor on technical parameters (continued)*
Tablica 1. *Ovisnost duljine remena transportera o tehničkim parametrima (nastavak)*

	9	10	11	12	13	14	15
1	B=1000 n=3 σ_k=3150 v=1,31 L_0=1450 L_1=1930	B=1000 n=3 σ_k=4000 v=1,31 L_0=1850 L_1=2460	B=1200 n=3 σ_k=1600 v=1,31 L_0=450 L_1=810	B=1200 n=3 σ_k=2000 v=1,31 L_0=650 L_1=1010	B=1200 n=3 σ_k=2500 v=1,31 L_0=900 L_1=1270	B=1200 n=3 σ_k=3150 v=1,31 L_0=1250 L_1=1600	B=1200 n=3 σ_k=4000 v=1,31 L_0=1600 L_1=2030
2	B=1000 n=3 σ_k=3150 v=1,68 L_0=1500 L_1=1940	B=1000 n=3 σ_k=4000 v=1,68 L_0=1850 L_1=2470	B=1200 n=3 σ_k=1600 v=1,68 L_0=500 L_1=820	B=1200 n=3 σ_k=2000 v=1,68 L_0=650 L_1=1030	B=1200 n=3 σ_k=2500 v=1,68 L_0=900 L_1=1280	B=1200 n=3 σ_k=3150 v=1,68 L_0=1250 L_1=1620	B=1200 n=3 σ_k=4000 v=1,68 L_0=1650 L_1=2060
3	B=1000 n=4 σ_k=3150 v=1,31 L_0=1850 L_1=2580	B=1000 n=4 σ_k=4000 v=1,31 L_0=2200 L_1=3280	B=1200 n=4 σ_k=1600 v=1,31 L_0=650 L_1=1080	B=1200 n=4 σ_k=2000 v=1,31 L_0=950 L_1=1355	B=1200 n=4 σ_k=2500 v=1,31 L_0=1300 L_1=1690	B=1200 n=4 σ_k=3150 v=1,31 L_0=1650 L_1=2160	B=1200 n=4 σ_k=4000 v=1,31 L_0=2050 L_1=2740
4	B=1000 n=4 σ_k=3150 v=1,68 L_0=1850 L_1=2590	B=1000 n=4 σ_k=4000 v=1,68 L_0=2200 L_1=3290	B=1200 n=4 σ_k=1600 v=1,68 L_0=700 L_1=1100	B=1200 n=4 σ_k=2000 v=1,68 L_0=950 L_1=1370	B=1200 n=4 σ_k=2500 v=1,68 L_0=1400 L_1=1720	B=1200 n=4 σ_k=3150 v=1,68 L_0=1650 L_1=2160	B=120 n=4 σ_k =4000 v=1,68 L_0=2050 L_1=2740
5	B=1000 n=5 σ_k=3150 v=1,31 L_0=2150 L_1=3230	B=1000 n=5 σ_k=4000 v=1,31 L_0=2450 L_1=4100	B=1200 n=5 σ_k=1600 v=1,31 L_0=950 L_1=1350	B=1200 n=5 σ_k=2000 v=1,31 L_0=1250 L_1=1690	B=1200 n=5 σ_k=2500 v=1,31 L_0=1650 L_1=2120	B=1200 n=5 σ_k=3150 v=1,31 L_0=1950 L_1=2670	B=1200 n=5 σ_k=4000 v=1,31 L_0=2300 L_1=3390
6	B=1000 n=5 σ_k=3150 v=1,68 L_0=2150 L_1=3240	B=1000 n=5 σ_k=4000 v=1,68 L_0=2450 L_1=4120	B=1200 n=5 σ_k=1600 v=1,68 L_0=950 L_1=1370	B=1200 n=5 σ_k=2000 v=1,68 L_0=1250 L_1=1720	B=1200 n=5 σ_k=2500 v=1,68 L_0=1650 L_1=2140	B=1200 n=5 σ_k=3150 v=1,68 L_0=1950 L_1=2700	B=1200 n=5 σ_k=4000 v=1,68 L_0=2300 L_1=3430
7	B=1000 n=6 σ_k=3150 v=1,31 L_0=2350 L_1=3870	B=1000 n=6 σ_k=4000 v=1,31 L_0=2650 L_1=4920	B=1200 n=6 σ_k=1600 v=1,31 L_0=1200 L_1=1620	B=1200 n=6 σ_k=2000 v=1,31 L_0=1550 L_1=2030	B=1200 n=6 σ_k=2500 v=1,31 L_0=1900 L_1=2540	B=1200 n=6 σ_k=3150 v=1,31 L_0=2200 L_1=3200	B=1200 n=6 σ_k=4000 v=1,31 L_0=2500 L_1=4060
8	B=1000 n=6 σ_k=3150 v=1,68 L_0=2350 L_1=3890	B=1000 n=6 σ_k=4000 v=1,68 L_0=2650 L_1=4940	B=1200 n=6 σ_k=1600 v=1,68 L_0=1200 L_1=1650	B=1200 n=6 σ_k=2000 v=1,68 L_0=1550 L_1=2060	B=1200 n=6 σ_k=2500 v=1,68 L_0=1900 L_1=2570	B=1200 n=6 σ_k=3150 v=1,68 L_0=2200 L_1=3240	B=1200 n=6 σ_k=4000 v=1,68 L_0=2500 L_1=4110

$$I_{\mathrm{k}} = R_{\mathrm{c}} \cdot \pi \cdot \left(1 - \frac{\alpha_{\mathrm{m}}}{180}\right) \cdot \left(I_{\mathrm{p}} + I_{\mathrm{t}} + I_{\mathrm{at}}\right), \tag{12}$$

where:
α_{m} – the angle made by two conveyors, °
I_{p} – the investments made in mining operation in order to adapt the underground workings,
I_{t} – the investments made for the construction of curvilinear conveyors,
I_{at} – the investment made for the adaptation of the new conveyor.

By comparing the specific transportation costs before and after the installation of curvilinear belt conveyors it is possible to estimate if such an activity is economically justified.

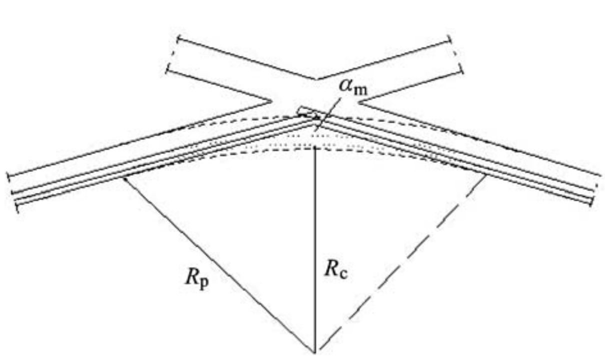

Figure 2 *Drawing of conveyor in curvature in underground workings*
Slika 2. *Nacrt transportera u zakrivljenju u podzemnim radovima*

After analyzing the current situation in Serbian coal mines, and on the basis of previous consideration, it may be stated that there are real conditions to install 6 curvilinear belt conveyors in main transportation spaces. The curve radius ranges from 650 m to 1300 m which secures a stable operation of the system. Deviation angles do not exceed 12 while the length of curve arc ranges from 57 m to 228 m.

5 Conclusion
Zaključak

The reduction of the number of conveyors in a belt conveyance system is an imperative need, because this gives rise to significant effects. In order to achieve this, it is necessary to make a preliminary analysis and to come to relevant parameters. The best effects are achieved by increasing the lengths of conveyors up to the highest limits, if other conditions allow that. The application of horizontal bend conveyors can also reduce their number. In coal mining these processes are very important, because significant economical and environmental effects can be achieved in this way.

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