



## **SIMULATION OF TRUCK HAULAGE AT THE OPEN PIT MINE MAJDANPEK**

## **SIMULACIJA KAMIONSKOG TRANSPORTA NA POVRŠINSKOM KOPU MAJDANPEK**

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**Abstract:** With the model simulation of discontinuous haulage system (excavator - truck), is accomplished optimization of ore truck haulage on the open pit mine "South mining district" of copper mine Majdanpek, where truck haulage is using as one of the basis types of ore haulage to the processing plant. The initial base for analysis selection of optimal ore haulage system on the open pit mine „South mining district” is define with the choice of combinations of existing loading and haulage equipment in the system with stationary crushing plant, with define annual ore production.

**Key words:** open pit mine, simulation, model, analysis, haulage system, optimization, costs.

**Apstrakt:** Simulacionim modeliranjem diskontinualnog transportnog sistema (bager - kamion) izvršena je optimizacija kamionskog transporta na površinskom kopu "Južni revir" Rudnika bakra Majdanpek, gde se kamionski transport koristi kao jedan od osnovnih vidova transporta rude od bagera do postrojenja za preradu. Optimizacija troškova transporta, u odnosu na ukupne troškove u rudniku, će obezbediti, povećanje profitabilnosti rada.

Polazna osnova za analizu izbora optimalnog transportnog sistema rude na površinskom kopu "Južni revir" definisana je izborom kombinacija postojeće utovarne i transportne opreme u sistemu sa stacionarnim drobilničnim postrojenjem, uz definisanu godišnju proizvodnju rude.

**Ključne reči:** površinski kop, simulacija, model, analiza, transportni sistem, optimizacija, troškovi.

### **1 INTRODUCTION**

Surface mining in the copper mine Majdanpek has taken place for more than four decades. The main characteristic of the up-to-present mine operation was mass exploitation with the application of modern techniques and technology in mining and processing mineral raw materials. Consequence of such intensive ore with regard to a lower and unequal exposing of a deposit, is the interruption of continuity in ore mining, at the deposit „Južni revir“(Southern mining district),

### **1 UVOD**

Površinska eksploatacija u rudniku bakra Majdanpek, odvija se više od četiri decenije. Osnovno obeležje dosadašnjeg rada rudnika je masovna eksploatacija uz primenu savremene tehnike i tehnologije u otkopavanju i preradi mineralnih sirovina. Posledica takve intezivne eksploatacije rude u odnosu na slabije i nesrazmerno raskrivanje ležišta, je prekid kontinuiteta otkopavanja rude, iz ležišta "Južni revir", što nalaže potrebu da se



which imposes a need for investing, in a certain period of time, in tailings mining and for making a reconstruction of open pit mine Southern mining district.

Surface mining of mineral raw materials constantly encounters the problem of capital investments in transportation equipment and of mining costs. This issue is especially perceptible in the exploitation of metallic deposits with a low content of useful component in the ore, as well as in the increase in depth of open pit mines, for the purposes of transporting the increasing quantity of both overburden and ore. Therefore there is a constant need for decreasing mining costs.

Simulation modelling has been applied for a long time, as one of the most efficient methods for monitoring, analysis and management of production processes and for decision-making in mining companies worldwide.

## 2 CURRENT SITUATION AND ISSUES IN RBM MAJDANPEK

In present conditions of business operations, taking into account the exchange rating of non-ferrous metals at the world market, high import costs of intermediate materials and spare parts, as well as almost 10 years poor efficiency in productivity or non-existence of the production, it is necessary to operationalize, where the preference is given to the development of the open pit mine "Južni revir" and its reconstruction is anticipated.

The objective of this Paper is to analyze the utilisation of truck haulage for transporting the residual ore from the open pit mine "Južni revir" involving sweep (web) – east and sweep – north, up to the primary crushing plant.

Since the planned mining dynamics for the open pit mine "Južni revir" is  $8,5 \times 10^6$  t, and therefore the equipment is adjusted and purchased according to the capacitance, we could say that the available equipment, which is counted upon in the future work, has its "reserves" in capacities (without taking into account faultlessness and availability of this equipment).

Future operation of the mine requires making analysis and finding possibilities of maximum usage of the equipment, which is very old and worn-out, with increased costs. A large part of

u određenom periodu investira u otkopavanju jalovine i izvrši rekonstrukcija površinskog kopa "Južni revir".

Površinska eksploatacija mineralnih sirovina konstantno se susreće sa problemom kapitalnih ulaganja u transportnu opremu i troškovima eksploatacije. Ovaj problem je posebno izražen pri eksploataciji metaličnih ležišta sa malim sadržajem korisne komponente u rudi i povećanjem dubine površinskih kopova, zbog potreba transportovanja sve većih količina kako otkrivke tako i rude. Zbog toga postoji stalna potreba za smanjenjem troškova eksploatacije.

Simulaciono modeliranje se već duže vreme primenjuje kao jedna od najefikasnijih metoda za praćenje, analizu i upravljanje proizvodnim procesima i donošenje poslovnih odluka u rudarskim preduzećima širom sveta.

## 2 TRENUTNO STANJE I PROBLEMATIKA U RBM-U MAJDANPEK

U današnjim uslovima privređivanja, stanju berze obojenih metala na svetskom tržištu, visokih cena uvoza repromaterijala i rezervnih delova, te gotovo 10 - godišnjeg slabog poslovanja ili nepostojanja proizvodnje neophodno je maksimalno operacionalizovati dalju proizvodnju u RBM-u Majdanpek, gde se daje prioritet razvoju kopa "Južni revir" i predviđa njegova rekonstrukcija.

Predmet ovog rada je da se analizira korišćenje kamionskog transporta za transport preostale rude iz površinskog kopa "Južni revir" obuhvaćeno zahvatom - istok i zahvatom - sever do primarnog drobilnog postrojenja.

Pošto projektovana dinamika eksploatacije za površinski kop "Južni revir" iznosi  $8,5 \times 10^6$  t, oprema je prema tome kapacitivno usklađena i nabavljena, može se reći da raspoloživa oprema, sa kojom se računa i u budućem radu, ima "rezervu" u kapacitetima (ne računajući ispravnost i raspoloživost te opreme).

Budući rad kopa, zahteva analiziranje i iznalaženje mogućnosti maksimalnog korišćenja opreme, koja je dosta stara i dotrajala, sa uvećanim troškovima. Veći deo opreme kako

the equipment, both discontinuous (excavator – truck) and continuous systems equipment (belt conveyor – spreader, HAC system) (stacker) requires detailed defectage (defectation) and activities for putting it into state of technical correctness with sufficient level of availability.

Long-term development of mining is conditioned by the mine configuration, width of workspaces at horizons and by the location of surrounding facilities. It is anticipated that the development should take place in three phases, that is, in three sweeps, which enlarges the open pit mine by edge and by depth up to the final outline during the operating period of mining.

### 3 DEVELOPPING A SIMULATION MODEL OF HAULAGE AT OPEN PIT MINE JUŽNI REVIR

Computer simulation comprises a process of development and usage of the simulation model in the software package TALPAC, Runge Software. For the analysis of selecting an optimal ore conveyance at the open pit mine "Južni revir", a model of discontinuous haulage system is developed (excavator - truck).

For the purpose of the reliability of the description and comprehension of the concept of discrete stochastic modelling, the model uses objective input data from the open pit mine "Južni revir", of the Coal Mine Majdanpek. By this approach for model presentation, it has been avoided the oversight of individual parameters and of real system processes through generalization of the modelling concept. The model represents the haulage system condition in ore mining in the period of time by the application of the process mode. Naturally, the model does not include all possible details which appear in real conditions during the operation of the haulage system; however, using known methods of verification of the application of certain equipment as technological parts, required precision of simulation results is achieved in terms of the considered issues.

Talpac is a software system used for defining the productivity and economy of the system operation (excavator – truck), using logics which models real haulage situations. In Talpac we define the haulage route, the truck that is to be use, loading unit, loading strategy, properties of the material and work organisation. Talpac takes all these raw data and performs many actions on

diskontinualne (bager - kamion) tako i opreme kontinualnih sistema (trakasti transporter - odlagač, HAC sistem) iziskuje detaljnu defektažu i aktivnosti na stavljanje u stanje tehničke ispravnosti sa dovoljnim nivoom raspoloživosti.

Dugoročni razvoj otkopavanja je uslovljen konfiguracijom kopa, širinom radnih prostora na etažama i lokacijom okolnih objekata. Predviđen je razvoj u tri faze odnosno zahvata, kojim se kop proširuje po obodu i po dubini do konačne konture u toku eksploatacionog perioda otkopavanja.

### 3 RAZVOJ SIMULACIONOG MODELA TRANSPORTA NA PK JUŽNI REVIR

Kompjuterska simulacija podrazumeva proces razvoja i korišćenja simulacionog modela u programskom paketu TALPAC, Runge Software. Za analizu izbora optimalnog transporta rude na površinskom kopu "Južni revir" razvijen je model diskontinualnog transportnog sistema (bager-kamion).

Radi verodostojnosti opisa i razumevanja koncepta diskretnog stohastičkog modeliranja, model koristi realne ulazne podatke sa površinskog kopa "Južni revir", Rudnika Bakra Majdanpek. Ovim pristupom prezentiranja modela izbegnuto je predviđanje pojedinih parametara i procesa realnog sistema generalizacijom koncepta modeliranja. Model oslikava stanje transportnog sistema na eksploataciji rude u vremenu primenom procesnog moda. Naravno model ne obuhvata sve moguće detalje koji se javljaju u realnim uslovima rada transportnog sistema, ali korišćenjem poznatih metoda verifikacije upotrebe pojedine opreme kao tehnoloških delova, dobijena je željena preciznost rezultata simulacije u okviru razmatrane problematike.

Talpac je softerski sistem koji se koristi za određivanje produktivnosti i ekonomičnosti rada sistema (bager - kamion) koristeći logiku koja modelira stvarne transportne situacije. U Talpac-u definišemo transportnu trasu, kamion koji koristimo, utovarnu jedinicu, utovarnu strategiju, osobine materijala i organizaciju rada. Talpac uzima ove neobrađene podatke i obavlja



them, including: production analysis, loading analysis, optimization of the size of the motor pool, engine power, useful load.

Simulation model of the haulage system, simulated in Talpac software package, contains five components for performing simulation system analysis (excavator - truck), see Figure 1.

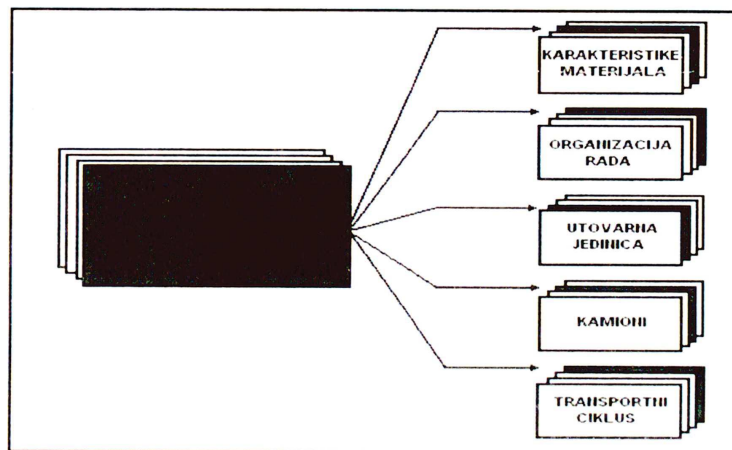


Figure 1 Structure of integral simulation model  
slika 1 Struktura integralnog simulacionog modela

brojne funkcije nad njima, uključujući analizu proizvodnje, utovarnu analizu, optimizaciju veličine voznog parka, snagu motora, korisnu nosivost.

Simulacioni model transportnog sistema, simuliranog u Talpac softverskom paketu, sadrži pet komponenti za izvođenje simulacione analize sistema (bager - kamion), slika 1.

Starting point for haulage analysis at the open pit mine "Južni revir" is defined by the selection of combinations of the existing loading and haulage equipment.

Discontinuous haulage systems (excavator – truck) are considered, as follows:

- ✓ MARION - 191M / WABCO 170D
- ✓ MARION - 191M / WABCO 190
- ✓ MARION - 191M / DRESSER 630E
- ✓ MARION - 191M - II / WABCO 170D
- ✓ MARION - 191M - II / WABCO 190
- ✓ MARION - 191M - II / DRESSER 630E
- ✓ BUCYRUS ERIE - 395B II / WABCO 170D
- ✓ BUCYRUS ERIE - 395B II / WABCO 190
- ✓ BUCYRUS ERIE - 395B II / DRESSER 630E.

Route of haulage ways is defined in such a manner that centres of masses of working horizons are connected to the location of crushing plant, with the capacity of 8,500,000 tons per year.

Together with defining the centre of residual mass of ore in the sweep (web) "East - North" (E - 90) at the open pit mine "Južni revir", a conveyance route of loaded and empty truck to the crushing plant (Figure 2).

Polazna osnova za analizu transporta na površinskom kopu "Južni revir" definisana je izborom kombinacija postojeće utovarne i transportne opreme.

Razmatrani su diskontinualni sistemi transporta (bager - kamion) i to:

- ✓ MARION - 191M / WABCO 170D
- ✓ MARION - 191M / WABCO 190
- ✓ MARION - 191M / DRESSER 630E
- ✓ MARION - 191M - II / WABCO 170D
- ✓ MARION - 191M - II / WABCO 190
- ✓ MARION - 191M - II / DRESSER 630E
- ✓ BUCYRUS ERIE - 395B II / WABCO 170D
- ✓ BUCYRUS ERIE - 395B II / WABCO 190
- ✓ BUCYRUS ERIE - 395B II / DRESSER 630E.

Transportna trasa puteva je definisana tako što su povezani centri masa radnih etaža sa lokacijom drobilnog postrojenja, pri kapacitetu od 8.500.000 tona godišnje.

Uz definisanje centra preostalih masa rude u zahvatu "Istok - Sever" (E - 90) na PK "Južni revir" definisana je trasa vožnje punog i praznog kamiona do drobilnog postrojenja (slika 2).



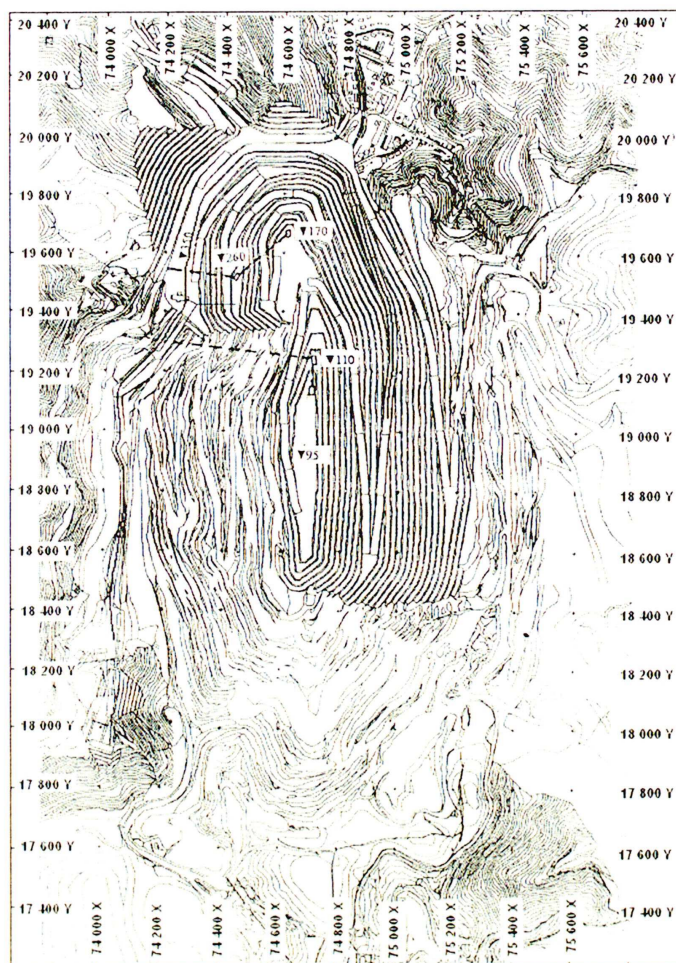


Figure 2 Haulage route of a truck at OPM "Južni revir"  
 slika 2 Transportna trasa kamiona na PK "Južni revir"

Data related to the material to be loaded and transported are stored in the material database. The data define working conditions (density of the material, loosening coefficient, filling coefficient) and characteristics of the material to be transported, in our case (andesite ore of the volumetric mass  $\gamma = 2.38 \text{ t/m}^3$ ).

On the basis of the adopted scheme of the operation of the open pit mine we define operating working hours for performing a technological haulage operation. In defining the organisation of work, we take into account operating and working hours of the equipment used in productivity simulations.

Data on technical and working characteristics of loading machines are located in the database. The data are structured by the type of loading machines.

Data on technical and working characteristics of trucks are located in the database. The data are structured by the type of trucks.

Podaci vezani za materijal koji se utovara i transportuje su pohranjeni u bazi podataka materijala. Podaci definišu radne uslove (gustinu materijala, koeficijent rastresitosti, koeficijent punjenja) i karakteristike materijala koji se transportuje, u našem slučaju (ruda andezita čija zapreminska masa iznosi  $\gamma = 2,38 \text{ t/m}^3$ ).

Na bazi usvojene šeme rada površinskog kopa određuje se operativno radno vreme za izvođenje tehnološke operacije transporta. Pri definisanju organizacije rada se računaju operativni i radni sati opreme što se koristi u simulacijama produktivnosti.

Podaci o tehno - eksploatacionim karakteristikama utovarnih mašina se nalaze u bazi podataka. Podaci su strukturirani po tipovima utovarnih mašina.

Podaci o tehno - eksploatacionim karakteristikama kamiona se nalaze u bazi podataka. Podaci su strukturirani po tipovima kamiona.

Information related to the haulage cycle is stored in the sample of haulage cycle.

Informacije vezane za transportni ciklus pohranjene su u uzorku transportnog ciklusa.

Stored information include schedule of operations for truck cycle, including:

Pohranjene informacije obuhvataju redosled operacija koje se javljaju za kamionski ciklus uključujući:

- |  |   |
|--|---|
| <ul style="list-style-type: none"> <li>- loading,</li> <li>- motion of loaded truck,</li> <li>- manoeuvre at the unloading point,</li> <li>- unloading,</li> <li>- comeback of an empty truck to the loading point and</li> <li>- manoeuvre at the loading point.</li> </ul> | <ul style="list-style-type: none"> <li>- utovar,</li> <li>- kretanje punog kamiona,</li> <li>- manevrisanje na mestu istovara,</li> <li>- istovar,</li> <li>- povratak praznog kamiona na mesto utovara, i</li> <li>- manevrisanje na mestu utovara.</li> </ul> |
|--|---|

For haulage modelling, Talpac requires that a haulage route is divided into a number of segments which represent inclined route sections and flat sections. A new segment is needed each time the terrain, which influences the truck speed, is changed.

Za modeliranje transporta Talpac zahteva da transportna trasa bude podeljena na niz segmenata koji predstavljaju deonice pod nagibom i ravne deonice. Novi segment je potreban svaki put kada se okolina koja kontroliše brzinu kamiona menja.

In order to make optimization of truck transport according to the criterion of minimal costs of system operation, it is necessary to be acquainted with, or to make assessment of, investment (capital) and operating costs of the system. Capital or investment costs represent costs of purchasing working equipment. Operating costs arise because of everyday operation of machines in the system. They comprise costs of: manpower, fuel, lubricants, tyres, servicing, spare parts, etc. In the absence of concrete data in the mine, the assessment of these costs is based to a great extent on the experience.

Da bi se izvršila optimizacija kamionskog transporta prema kriterijumu minimalnih troškova rada sistema neophodno je poznavati ili izvršiti procenu investicionih (kapitalnih) i operativnih troškova sistema. Kapitalni ili investicioni troškovi, predstavljaju troškove nabavke opreme za rad. Operativni troškovi nastaju usled svakodnevnog rada mašina u sistemu. Oni obuhvataju troškove: radne snage, goriva, maziva, ulja, guma, servisiranja, rezervnih delova itd. U nedostatku konkretnih podataka sa rudnika procena ovih troškova se u velikoj meri zasniva na iskustvu.

#### 4 OPTIMIZATION OF THE DISCONTINUOUS HAULAGE SYSTEM

#### 4 OPTIMIZACIJA DISKONTINUALNOG TRANSPORTNOG SISTEMA

Optimization of the discontinuous haulage system (excavator – truck) is made by means of Software package Talpac at open pit mine "Južni revir", for the haulage route (E - 275) – ore crushing.

Softverskim paketom Talpac izvršena je optimizacija diskontinualnog transportnog sistema (bager - kamion) na površinskom kopu "Južni revir", za transportnu trasu (E - 275) – drobljenje rude.

Using the existing loading and haulage equipment and with 8.5 million tons annual ore production, 9 scenarios are performed, and summary of results is given in the Table 1.

Korišćenjem postojeće utovarne i transportne opreme i godišnjom proizvodnjom od 8.500.000 t rude, izvršeno je 9 scenarija, a sumarni pregled rezultata dat je u tabeli 1.

On the basis of the given table results of the simulation, it is possible to show that on a diagram (Figure 3).

Na osnovu dobijenih tabelarnih rezultata simulacije, moguće je to prikazati i dijagramski (slika 3.).



Table 1 Summary of simulation results

Tabela 1 Pregled rezultata simulacija

Scenario	T1-Actual No. Of Trucks	Fleet Production Per Year tonnes	Production Change (%)	Fleet Discount Capital Cost \$/tonnes	Fleet Discount Operating Cost \$/tonnes	Fleet Discount Avg. Cost \$/tonnes
Ia 191M / 170D						
Ib 191M / 190						
Ic 191M / 630E						
IIa 191M - II / 170D	6.00	8,278,037.32	-22.27	0.26	0.64	0.90
IIb 191M - II / 190						
IIc 191M - II / 630E						
IIIa 395B - II / 170D						
IIIb 395B - II / 190						
IIIc 395B - II / 630E						

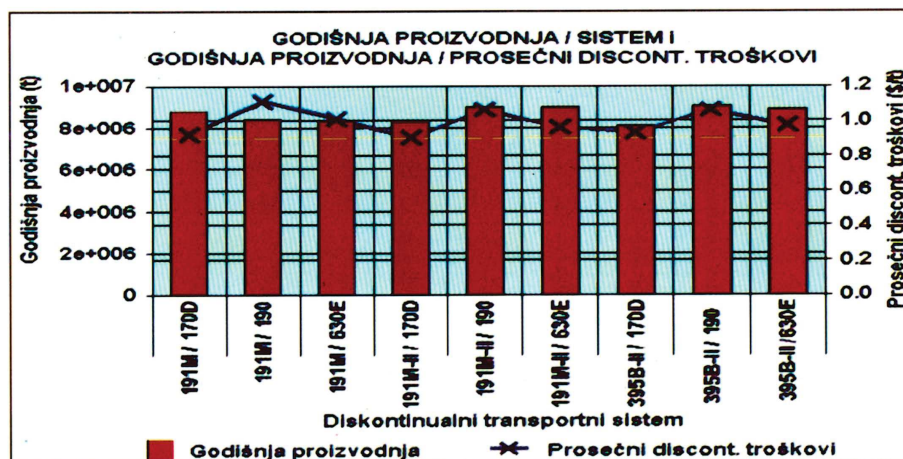


Figure 3 Diagram of average discounted costs for the analyzed systems  
slika 3 Dijagram prosečnih diskontovanih troškova za analizirane sisteme

## 5 CONCLUSION

Using simulation modelling of discontinuous haulage systems (excavator - truck), by applying the software package TALPAC 8.0 (Runge mining co. Australia), the optimization of truck transport is made, at the open pit mine "Južni revir", of the Coal Mine Majdanpek, where truck transport is used as one of the basic types of ore conveyance.

Simulation analysis, shown in this Paper, has been carried out on the example of usage of the existing loading and haulage mine mechanization, as well as on the basis of annual mine output.

According to findings of simulation experiments and on the basis of techno-economic analysis, we may conclude that at 8.5 mil tons annual ore output of an open pit mine, discontinuous haulage system MARION 191M-II / WABCO 170D (excavator with the shovel capacity of 15.3 m<sup>3</sup> and truck with carrying capacity of 154 tons) have the lowest discounted costs, which were the basic criterion in economic assessment of the model of the haulage system.

## 5 ZAKLJUČAK

Simulacionim modeliranjem diskontinualnih transportnih sistema (bager - kamion) primenom softverskog paketa TALPAC 8.0 (Runge mining co. Australija) izvršena je optimizacija kamionskog transporta, na površinskom kopu "Južni revir", Rudnika bakra Majdanpek, gde se kamionski transport koristi kao jedan od osnovnih vidova transporta rude.

Simulaciona analiza, prikazana u ovom radu izvedena je na primeru korišćenja postojeće utovarne i transportne mehanizacije rudnika, kao i na osnovu godišnje proizvodnje rudnika.

Prema dobijenim rezultatima simulacionih eksperimenata i na osnovu tehno - ekonomske analize, može se zaključiti da pri godišnjem kapacitetu kopa od 8.500.000 t rude, diskontinualni transportni sistem MARION 191M-II / WABCO 170D (bager zapremine kašike 15,3 m<sup>3</sup> i kamion nosivosti 154 tone) daje najniže prosečne diskontovane troškove, koji su bili osnovni kriterijum pri ekonomskoj oceni modela transportnog sistema.

Average discounted costs of operation of this system for the given mine capacity amount to 0.90 \$/t, which makes them 2 - 23% lower than costs incurred when using other alternative systems currently available in the mine.

Prosečni diskontovani troškovi rada ovog sistema za posmatrani kapacitet kopa iznose 0.90 \$/toni i oni su manji za oko 2 - 23 %, od troškova koji nastaju sa drugim alternativnim sistemima kojima rudnik trenutno raspolaže.

#### REFERENCES / LITERATURA

- [1] Borović, R.: *Calculations of transportation facilities*. Faculty of Mining and Geology, Belgrade, 1987.
- [2] Kolonja, B., Stanić, R., Hamović, J.: *Simulation of haulage systems in mining using AutoMod*. International periodical Transport and Logistics, 2001.
- [3] Kolonja, B., Stanić, R., Vasiljević, N.: *By way of simulations to the third millennium - modelling of technological systems in mining*. Periodical Info, 1988.
- [4] Kolonja, B., Stanić, R., Stojanović, L.: *Simulation of haulage systems in mining*. IV International Symposium on haulage and hoisting, pp 48-52, Belgrade, 1999.
- [5] Jenić, D., Savić, M., Mitrović, S. et al.: *Feasibility Study for the Open pit mine „Južni revir of the Coal Mine Majdanpek*. Copper Institute Bor, 2001.

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