



## CORRELATION OF TRANSPORTATION AND LOGISTICS SYSTEMS IN MINERAL ORE MINING

### POVEZANOST TRANSPORTNIH I LOGISTIČKIH SISTEMA U EKSPLOATACIJI MINERALNIH SIROVINA

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**Abstract:** Manufacturing companies which use mineral raw materials have a need for the scheduled, reliable and timely supply. This may be achieved by means of appropriate transportation systems. This paper deals with the correlation of transportation and logistics systems in mining and delivery of mineral raw materials.

**Key words:** Transportation systems, Logistics, Mining.

**Apstrakt:** Proizvodne kompanije koje koriste mineralne sirovine imaju potrebu za planiranim, pouzdanim i blagovremenim snabdevanjem. To je moguće ostvariti odgovarajućim transportnim sistemima. U ovom radu se obrađuje povezanost transportnih i logističkih sistema u eksploataciji i dostavi mineralnih sirovina.

**Ključne reči:** Transportni sistemi, logistika, rudarstvo.

### 1 INTRODUCTION

One of the basic definitions of logistics is that it is a science of planning, controlling and managing the transportation, storage and other material and non-material operations necessary for the process of the delivery of mineral ores and materials to manufacturing companies for processing of ore, materials and semi-finished products, and the delivery of finished products to consumers according to their needs. The logistics also includes other activities relating to securing, processing and storing relevant information. We may also state that the logistics represents a set of methods for managing certain flows, whereas they may be classified as material, information and financial flows.

### 1 UVOD

Jedna od osnovnih definicija logistike je da je to nauka o planiranju, kontroli i upravljanju transportom, uskladištenjem i drugim materijalnim i nematerijalnim operacijama potrebnim u procesu dopreme sirovina i materijala proizvodnim preduzećima za preradu sirovina, materijala i polufabrikata, kao i dostava gotovih proizvoda do potrošača prema njihovim potrebama. Logistika obuhvata i ostale operacije koje se odnose na obezbeđenje, obradu i čuvanje odgovarajućih informacija. Može se, takođe, reći da logistika predstavlja skup metoda za upravljanje određenim tokovima, pri čemu se oni mogu podeliti na materijalne, informacione i finansijske.

The Logistics dealing with material flows, whether it is manufacturing, commercial or warehouse logistics, is closely connected to the transportation, without which there are no logistic processes. Even financial and information logistics represent flows of finances and information. Logistics and transportation systems are multi-interrelated in a company, and therefore it is difficult to define the point where a logistics system ends and a transportation system starts and vice versa.

The objective of this paper is to indicate some aspects of the correlation of transportation and logistics systems in mineral ore mining, by observing mining in general, with delivery of products to primary consumers. Thereat more attention shall be paid to defining the warehousing in transportation, and logistics systems.

## 1 BASIC PRINCIPLES OF THE TRANSPORTATION AS A PART OF THE LOGISTICS SYSTEM

Transportation of mineral raw materials mainly falls under internal transportation or conveyance, if it is about the mine itself, and it has also elements of external transportation where a raw material is delivered to a primary consumer. Regardless of that which of these types of transportation is in question, the main mission of logistics is the optimization of transportation systems, i.e. minimization of all costs of logistics systems.

The main tasks of so-called **Transportation Logistics** may be set as necessary steps in order to make preparations for the system optimization:

- Opting for an operation mode of transportation systems (continuous or discontinuous),
- Selecting a type of means of transportation or conveyance (belts, trucks, rail transportation etc.)
- Adjusting the transportation system to contact systems (manufacturing and warehousing),
- Bringing in line of a work plan with different transportation methods (in multimodal transport),
- Assuring the technological unity of the transportation and the warehousing in the system,
- Selecting rational delivery routes etc.

Logistika koja se bavi materijalnim tokovima, bilo da je reč o proizvodnoj, komercijalnoj ili skladišnoj, je veoma usko povezana sa transportom, bez koga nema logističkih procesa. Čak i finansijaska i informaciona logistika predstavljaju kretanje finansija i informacija. Logistički i transportni sistemi se u jednoj kompaniji višestruko prepliću, tako da je teško definisati gde prestaje logistički a počinje transportni sistem i obrnuto.

Cilj ovog rada je da ukaže na neke aspekte povezanosti transportnih i logističkih sistema u eksploataciji mineralnih sirovina, posmatrajući eksploataciju u širem smislu sa dostavom proizvoda primarnim potrošačima. Pri tome će više pažnje biti posvećeno definisanju uskladištenja u transportnim odnosno logističkim sistemima.

## 1 OSNOVNE POSTAVKE TRANSPORTA KAO DELA LOGISTIČKOG SISTEMA

Transport mineralnih sirovina spada u najvećem delu u unutrašnji transport, ako je reč o samom rudniku, a ima i elemente spoljašnjeg transporta kada se sirovina dostavlja primarnom potrošaču. Bez obzira koji od tih vrsta transporta u pitanju, osnovni zadatak logistike je optimizacija transportnih sistema, odnosno minimiziranje svih troškova logističkih sistema.

Osnovni zadaci tzv. **transportne logistike** se mogu postaviti kao neophodni koraci u cilju pripreme za optimizaciju sistema:

- opredeljivanje za način rada transportnih sistema (kontinualni ili diskontinualni),
- izbor vrste transportnih sredstava (trake, kamioni, šinski transport i dr.)
- uskladištanje sistema transporta sa dodirnim sistemima (proizvodnim i skladišnim),
- usaglašavanje plana rada sa različitim načinima transporta (kod kombinovanog transporta),
- obezbeđenje tehnološkog jedinstva transporta i uskladištenja u sistemu,
- izbor racionalnih maršrute dostave itd.

In the transportation technology itself it is necessary to assure that three basic requirements are met:

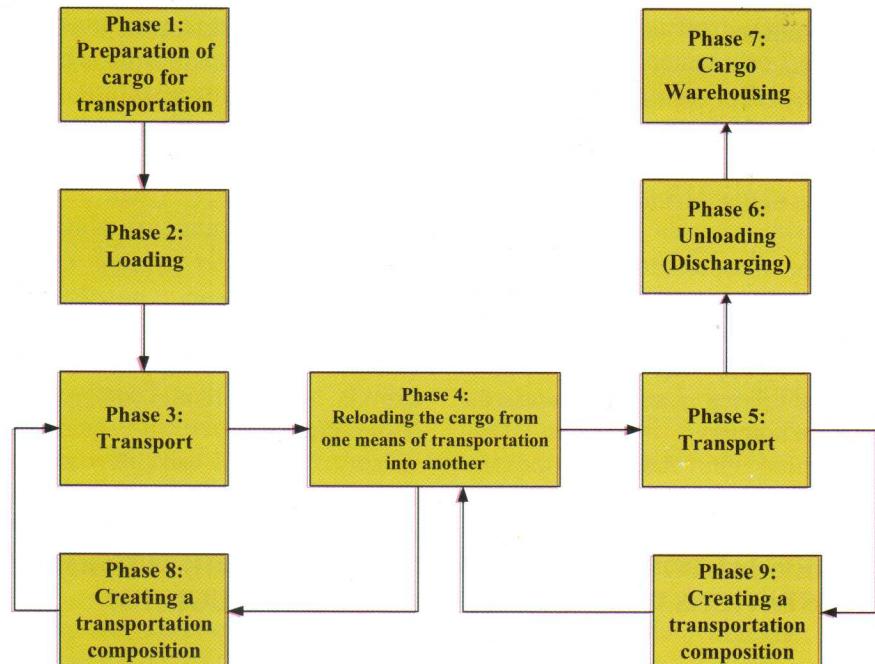
- Parsing and analysis of each process in the transportation,
- Coordination and gradualness,
- Common objective (unambiguity of the effect).

Technological transportation flow chart, as a part of the logistics system may be presented through a diagram as in Figure 1. This diagram shows different phases in case of multimodal transport with the application of two or more types of means of transportation.

U samoj tehnologiji transporta neophodno je voditi računa o tri osnovna zahteva koji moraju biti ispunjeni:

- raščlanjivanje i analiza svakog procesa u transportu,
- koordinacija i etapnost,
- zajednički cilj (jednoznačnost dejstva).

Tehnološka šema transporta, kao dela logističkog sistema može se predstaviti preko šeme na slici 1. Na ovoj šemi je dat prikaz različitih faza za slučaj da se radi o kombinovanom transportu sa primenom dve ili više vrsta transportnih sredstava.



*Figure 1 Technological flow chart of freight transportation by different types of transportation systems*

*slika 1 Tehnološka šema transporta tereta različitim vrstama transporta*

Mineral ore materials, obtained in the process of mine excavation, are transported to the surface, outside the limits of the mine, and are delivered to primary consumers. The most important logistics systems, for the mine itself, are those which provide intermediate goods for the production (building material, support, cement, sand, lubricants, explosives etc.), energy (electrical energy, fuels), spare parts of machines and devices etc. On the other hand, a mine as a production system provides raw materials for smelting works, thermal power plants, heating stations and other production systems.

Mineralne sirovine, koje se dobijaju u procesu otkopavanja u rudniku, se transportuju na površinu, van granica rudnika i dostavljaju se primarnim potrošačima. Za sam rudnik najvažniji logistički sistemi su oni koji obezbeđuju repromaterijal za proizvodnju (građa, podgrada, cement, pesak, maziva, eksplozivi i sl.), energiju (električnu energiju, goriva), rezervni delovi mašina i uređaja itd. Sa druge strane rudnik kao proizvodni sistem obezbeđuje sirovine za topionice, termoelektrane, toplane i druge proizvodne sisteme.

Logistics transportation systems in the production of mineral raw materials have two directions: towards a mine (ensuring the mine production) and from a mine, ensuring the supply of consumers with raw materials. Both systems have their specificities, but also common principles and operation modes.

The quality of transportation service, regardless of who is carrying it out, is assessed in many ways. However, transportation quality indicators, with a view to ensuring the logistics of companies using mineral raw materials, may be classified into four groups:

1. quality assurance of ore transportation which provide for consumers, according to their needs,
2. preserving the properties of transported loads during transportation in accordance with consumers' needs,
3. Stability in supply in all conditions,
4. Elimination of external factors in complex assessment of a transportation service quality (politics, bribery, nepotism and the like).

In order to enhance the transportation quality within logistics systems, it is necessary to, in compliance with the standards, periodically control the service quality. It is achieved by applying opinion poll and other methods, where service users may assess the work in transportation industry.

## **2 STABILIZATION OF SYSTEMS FOR SUPPLYING THERMAL POWER PLANTS AND HEATING STATIONS WITH COAL**

To the group of the most significant consumers in energy mining belong thermal power capacities which sell electrical and thermal energy to their users. The production of both energy types requires a stable supply with energy fuels, where the coal conveyance, in addition to its production, has a very significant role.

Contemporary conditions of coal mining, regardless of that it is open-pit or underground mining, imply the continuous method of mining.

This excavation and transportation method is characterized by irregularity and variation of capacities. In order to define a stable supply of consumers with coal it is necessary to determine the irregularity degree  $k_n$ :

Logistički transportni sistemi u proizvodnji mineralnih sirovina imaju dva smera: za rudnik (obezbeđenje proizvodnje rudnika) i od rudnika za obezbeđenje snabdevanja potrošača sirovinama. I jedan i drugi sistem imaju svoje specifičnosti, ali i zajedničke postavke i principe rada.

Kvalitet transportne usluge, bez obzira na to ko je vrši, ocenjuje se na više načina. Međutim, pokazatelji kvaliteta transporta u cilju obezbeđenja logistike kompanija koji koriste mineralne sirovine, mogu se svrstati u četiri grupe:

1. obezbeđenje kvaliteta transporta sirovina kojim su obezbeđene potrebe potrošača,
2. očuvanje svojstava transportnih tereta u toku transporta u skladu sa potrebama potrošača,
3. Stabilnost snabdevanja u svim uslovima,
4. Isključenje spoljnih faktora pri kompleksnoj oceni kvaliteta transportne usluge (politika, korupcija, nepotizam i sl.).

Da bi se povećao kvalitet transporta u okviru logističkih sistema neophodno je, shodno standardima, periodično proveravati kvalitet usluge. To se postiže primenom anketnih i drugih metoda, gde korisnici usluga ocenjuju rad na transportu.

## **2 STABILIZACIJA SISTEMA ZA SNABDEVANJE TERMOELEKTRANA I TOPLANA UGLJEM**

Među najvažnije potrošače u energetskom rudarstvu spadaju termoenergetski kapaciteti koji svojim korisnicima prodaju električnu i toplotnu energiju. Proizvodnja oba oblika energije zahteva stabilno snabdevanje energentima, gde transport uglja, pored proizvodnje, ima značajnu ulogu.

Savremeni uslovi eksploatacije uglja, bez obzira na to da li je reč o površinskom ili podzemnom otkopavanju, podrazumeva kontinualni način dobijanja.

Ovaj način otkopavanja i transporta se odlikuje neravnomernošću i varijacijom kapaciteta. Da bi se definisalo stabilno snabdevanje potrošača ugljem potrebno je utvrditi stepen neravnomernosti  $k_n$ :

$$k_n = \frac{M(q_t) + z \cdot \sigma(q_t)}{M(q_t)} = 1 + z \cdot \sigma_t \quad (1)$$

Where:  $\sigma(q_t)$  – medium-square deviation of the volume of coal inflow on a transportation system,  
 $M(q_t)$  – mathematical expectation (medium value) of coal inflow on a transportation system,  
 $z$  – probability parameter, whereby the irregularity degree is determined,  
 $\sigma_t$  – variation coefficient represents the relation between a medium-square deviation and mathematical expectation of coal inflow rate,

Irregularity degree may have a high impact on the stable coal supply. Therefore it is necessary to undertake certain steps with a view to reducing irregularities and their minimizing. One of the ways to achieve this is introducing warehousing facilities within a transportation system or at its end within the circle of the consumer. There are many types of warehouse facilities, but the most frequent ones in the ore conveyance are various types of bunkers and open or closed points.

Warehouse facilities basically represent logistics facilities and are equipped with suitable devices enabling the functioning of the transportation and the supply of consumers with coal. In order to realize one of the main objectives of the logistics and to reduce coal delivery costs, it is necessary to carry out the optimization of parameters of these facilities.

The time of loading the warehouse facility with belt conveyors depends on its volume  $V_b$ , belt speed which loads the bunker  $v_1$ , with belt width  $B$  and proportionality coefficient for belt effectiveness  $K$ :

$$t_u = \frac{60 \cdot V_b}{K \cdot (0,9 \cdot B - 0,05)^2 \cdot v_t} \quad (2)$$

For the optimization of warehouse parameters it is necessary to define medium speed of loading the warehouse, which depends on the coefficient of the machine time of the coal delivering system  $K_m$  and the assumption that the belt conveyor behind the warehouse is operational  $p_1$ :

$$k_n = \frac{M(q_t) + z \cdot \sigma(q_t)}{M(q_t)} = 1 + z \cdot \sigma_t \quad (1)$$

Gde su:  $\sigma(q_t)$  – srednjekvadratno odstupanje veličine dotoka uglja na transportni sistem,  
 $M(q_t)$  – matematičko očekivanje (srednja vrednost) dotoka uglja na transportni sistem,  
 $z$  – parameter verovatnoće sa kojim se određuje stepen neravnomernosti,  
 $\sigma_t$  – koeficijent varijacije koji predstavlja odnos srednjekvadratnog odstupanja i matematičkog očekivanja dotoka uglja,

Stepen neravnomernosti može imati velikog uticaja na stabilno snabdevanje ugljem. Zbog toga je neophodno preduzimati određene korake u cilju smanjenja neravnomernosti i njegovog suočenja na najmanju moguću meru. Jedan od načina na koji se to postiže je uvođenje objekata za uskladištenje u okviru transportnog sistema ili na njegovom kraju u krugu samog potrošača. Postoji više tipova objekata za uskladištenje, ali u transport mineralnih sirovina se najčešće sreću razne vrste bunkera i otvoreni ili zatvoreni skladovi.

Objekti za uskladištenje u suštini predstavljaju logističke objekte i opremljeni su odgovarajućim uređajima koji omogućuju funkcionisanje transporta i snabdevanje potrošača ugljem. Da bi se jedan od osnovnih ciljeva logistike ostvario i snizili troškovi dostave uglja, potrebno je izvršiti optimizaciju parametara ovih objekata.

Vreme punjenja objekta za uskladištenje transporterima sa trakom zavisi od njegove zapremine  $V_b$ , brzine trake koja puni bunker  $v_1$ , širine trake  $B$  i koeficijenta proporcionalnosti za efektivnost trake  $K$ :

$$t_u = \frac{60 \cdot V_b}{K \cdot (0,9 \cdot B - 0,05)^2 \cdot v_t} \quad (2)$$

Za optimizaciju parametara skladišta potrebno je odrediti srednju brzinu punjenja skladišta, koja zavisi od koeficijenta mašinskog vremena sistema koji doprema ugalj  $K_m$  i verovatnoće da je transporter iza skladišta u radnom stanju  $p_1$ :

$$v = K_m \cdot q - p_1 \cdot Q_t \quad (3)$$

Where:  $q$  – intensity of coal inflow  
 $Q_t$  – acceptance capacity of the conveyor behind the warehouse.

The speed of loading ( $v_1$ ) and unloading ( $v_2$ ) of a warehouse, with certain approximations, can be defined using the following formulas:

$$v_1 = K_m \cdot p_1 \cdot q(1 - p_1) \quad (4)$$

$$v_2 = K_m \cdot p_1 \cdot Q_t \left(1 - \frac{q - Q_t}{Q_t}\right), \quad (5)$$

The diagram (Figure 2) shows the relation of speeds of loading and unloading of the bunker for different intensities of coal inflow and different width and speed of a belt.

Gde su:  $q$  – intenzitet dotoka uglja  
 $Q_t$  – prijemna moć transportera iza skladišta.

Brzina punjenja ( $v_1$ ) i pražnjenja ( $v_2$ ) skladišta, uz određene aproksimacije, može se odrediti pomoću sledećih obrazaca:

$$v_1 = K_m \cdot p_1 \cdot q(1 - p_1) \quad (4)$$

$$v_2 = K_m \cdot p_1 \cdot Q_t \left(1 - \frac{q - Q_t}{Q_t}\right), \quad (5)$$

Na dijagramu (slika 2) je prikazan odnos brzina punjenja i pražnjenja bunkera za različite intenzitete dotoka uglja i različite širine i brzine trake.

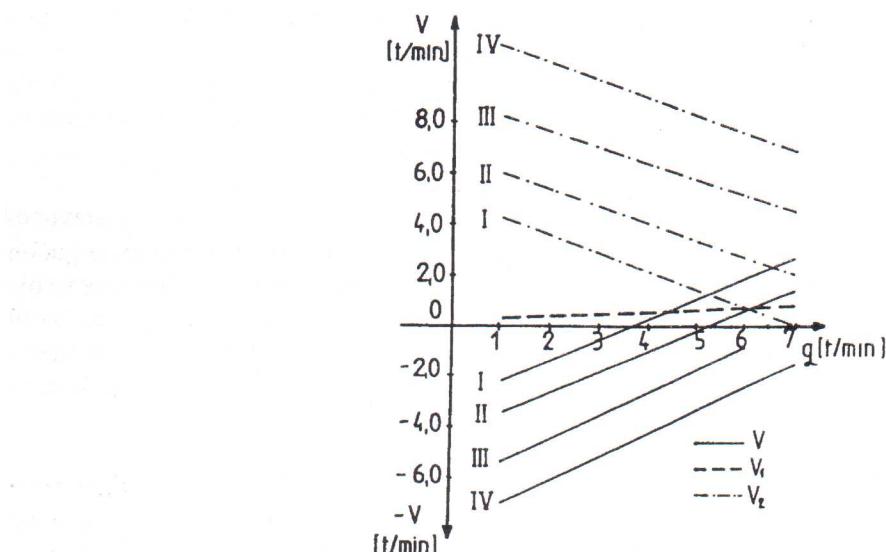


Figure 2 Change in speed of loading and unloading the coal bunker  
slika 2 Promena brzina punjenja i pražnjenja bunkera uglja

Further optimization of the warehouse parameters is made by introducing, in addition to technical parameters, economic parameters, such as operating costs of the warehouse, possible losses due to the irregularity and instability of the coal delivery system to consumers.

Dalja optimizacija parametara skladišta se vrši uvođenjem, pored tehničkih parametara, i ekonomskih poput troškova eksploracije skladišta, mogućih gubitaka usled neravnomernosti i nestabilnosti sistema dopreme uglja potrošačima.

### 3 CONCLUSION

Correlation of transportation and logistics systems in manufacturing companies and companies supplied by those, is known and

### 3 ZAKLJUČAK

Povezanost transportnih i logističkih sistema u proizvodnim kompanijama i kompanijama koje one snabdevaju je poznata i evidentna u skoro

evident in almost all industries. The supply of production plants with mineral and energy raw materials is also the important logistic process, which requires a stable and reliable delivery of necessary raw materials. In order to achieve this, it is necessary to carry out the optimization of transportation systems which perform the function of consumer supply.

svim privrednim granama. Snabdevanje proizvodnih pogona mineralnim i energetskim sirovinama je, takođe, važan logistički process, koji zahteva stabilnu i pouzdanu dostavu potrebnih sirovina. Da bi se to moglo ostvariti neophodno je da se izvrši optimizacija transportnih sistema koji obavljaju funkciju snabdevanja potrošača.

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**Reviewal / Recenzija:** Prof. Ing. Jan Boroška, CSc