Saimaa University of Applied Sciences
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COMPARISON OF DIFFERENT TRANSPORTATION MODES. CASE OOO NVT

Bachelor's Thesis 2010

ABSTRACT
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Comparison of different transportation modes. Case NVT, 52 pages, 3 appendices
Saimaa University of Applied Sciences, Lappeenranta
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The subject of this thesis was to analyze the efficiency of transportation in Moscow region business environment and compare the delivery by different transportation modes. Transportation has been carried out from consolidation warehouse of wine producing case company OOO NVT to its distribution centre. The main purpose was to give the reader and overall impression of transportation efficiency today in general, as well as its most important elements for Moscow region.

The work is divided into two distinct parts; theory and practical analysis of different alternatives in transportation. In the theory part, the reader will gain basic understanding of physical distribution main aspects and development history, general information on place of transportation in physical distribution processes and main operational factors for efficient transportation. Next, the reader will get acquainted with internal and external characteristics for different transportation modes. The practical part includes a quantitative analysis of road, railroad and water delivery, as well as graphical evaluation of received results. Some political aspects, as delays in railroad transportation related to Russian state monopoly, were not taken under particular consideration.

As a result of this thesis it can be concluded that due to the increased importance for transportation efficiency in respect to logistical costs, companies are faced with a lot of challenges. Different transportation modes are suitable for different delivery times and amounts. The most flexible transportation mode is road transport, especially due to short distances, which at the same time relatively expensive. According to received results water transportation is most cost-efficient for case company, but on the other hand it requires more precise evaluation of demand, which so far was not very effective, and takes more time to deliver. With more increasing distance water option of delivery becomes more efficient. This fact is very essential when OOO NVT will consider location of their warehouses in the future. It became obvious that due to cost and time issues many companies are struggling to develop their own demand forecast and analysis systems, which will have a positive influence on transportation efficiency in Russia.

Key words: physical distribution, transportation efficiency, delivery modes, road transportation, railroad transportation, water transportation, consolidation warehouse, Moscow region, wine industry

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Tämän opinnäytön tarkoituksena oli tarkastella kuljetuksen tehokkuutta Moskovan alueella ja verrata keskenään toimituksia eri kuljetusmuodoilla. Toimitukset suoritettiin viiniä tuottavan kohdeyrityksen OOO NVT varastosta jakelukeskukseen. Päätarkoituksena oli antaa lukijalle yleiskäsitys nykyaikaisten kuljetusten tehokkuudesta sekä esittää sen tärkeimmät elementit Moskovan alueella.

Opinnäytetyö on jaettu kahteen eri osaan; teoriaan ja käytännön analyysiin kuljetuksen eri vaihtoehdoista. Teoriaosa antaa lukijalle käsityksen fyysisen jakelun tärkeimmistä näkökohdista ja sen kehityksen historiasta, yleistä tietoa kuljetusten paikasta fyysisen jakelun prosessissa ja tehokkaan kuljetuksen keskeisistä toiminnallisista tekijöistä. Seuraavaksi lukija tutustuu eri kuljetusmuotojen sisäisiin ja ulkoisiin ominaisuuksiin. Käytännön osa on kvantitatiivinen analyysi maantie-, rautatie- ja vesitiekuljetuksista sekä graafinen arviointi saatujen tulosten perusteella. Jotakin poliittisia seikkoja, kuten viivästyksiä rautatien kuljetuksissa johtuen Venäjän valtion monopoliasemasta ei ole erityisesti otettu huomioon.

Opinnäytön perusteella voidaan todeta, että kuljetuksilla on yhä tärkeämpi rooli logistiikkakustannuksissa ja yritykset joutuvat kohtaamaan monia haasteita. Maatiekuljetukset ovat muita joustavampia, mutta samalla suhteellisesti kalliita. Saatujen tuloksien mukaan vesikuljetukset ovat kohdeyritykselle kaikkein kustannustehokkaimmat, mutta toisaalta se vaatii kysynnän tarkempaa arviointia, mitä toistaiseksi ei kehitetty hyvin. Kuljetuksen etäisyyden kasvaessa vesikuljetuksesta tulee yhä tehokkaampi vaihtoehto. Tämä päätelmä on oleellinen OOO NVT:n harkitessa uusien varastojen sijaintia. Opinnäytetyötä tehdessä tuli myös selväksi, että monet yritykset pyrkivät kehittämään omia kysynnän ennustejärjestelmiä, jolla on myönteinen vaikutus kuljetuksien tehokkuuteen Venäjällä.

Hakusanat: physical distribution, transportation efficiency, delivery modes, road transportation, railroad transportation, water transportation, consolidation warehouse, Moscow region, wine industry

CONTENTS:

ABBREVIATIONS:

CIF is a trade term requiring the seller to arrange for the carriage of goods by sea to a port of destination, and provide the buyer with the documents necessary to obtain the goods from the carrier (Investopedia ULC 2010).

ECR or Efficient Consumer Response is the realization of a simple, fast and consumer driven system, in which all links of the logistic chain work together, in order to satisfy consumer needs with the lowest possible cost (ECR Board 1995).

FOB is a shipping term which indicates that the supplier pays the shipping costs (and usually also the insurance costs) from the point of manufacture to a specified destination, at which point the buyer takes responsibility (WebFinance, Inc. 2010).

Roll-on/roll-off (RORO or ro-ro) ships are vessels designed to carry wheeled cargo such as highway trailers, railcars, and other wheeled cargo or vehicles, from and to specially adapted ships (Soenmez-transport-logistik, 2010).

ROI is a performance measure used to evaluate the efficiency of an investment or to compare the efficiency of a number of different investments. To calculate ROI, the benefit (return) of an investment is divided by the cost of the investment; the result is expressed as a percentage or a ratio. The return on investment formula:

$$\text{ROI} = \frac{(\text{Gain from Investment} - \text{Cost of Investment})}{\text{Cost of Investment}}$$

(Investopedia ULC 2010.)

1. INTRODUCTION

This topic was chosen because nowadays transportation costs occupy an essential part of total costs, and efficient transportation management can be a huge opportunity for savings. Transport systems face requirements to increase their capacity and to reduce transportation costs. Freight transportation has been observed to absorb between one-third and two-thirds of total logistics costs. Unfortunately, however, often transportation management as whole, as well as its significant parts, for example, routing or transportation modes remain without proper attention. Costs of implementing different modes of transportation tend to be undervalued, which can lead to inefficiency and inequity of distribution system. Efficient transportation management can possibly decrease base costs of goods, at the same time increasing competitiveness of those goods and profitability of the whole supply chain.

Frequently, enterprises must answer the question about how to route freight through the transport system. Despite that, it's essential to take into consideration overloaded traffic conditions in the Moscow region, as well as legal and environmental aspects of transportation. Breaking rules related to both above mentioned aspects can lead into fines and penalties, which in turn will decrease the efficiency of distribution system.

The purpose of this thesis is to determine proper evaluation criteria for freight transportation, compare the costs of transportation options and select the most appropriate and efficient transportation mode according to those criteria. As it can be imagined efficient and economically successful distribution network is partly dependent on cost efficiency of transportation management. On the other hand, selection of proper transportation mode will definitely increase the profitability of transportation management. Economic analysis has a lot to contribute to sustainable transport management. It can help define issues, assess benefits and costs, determine what factors nowadays have an increasing importance and what are less significant.

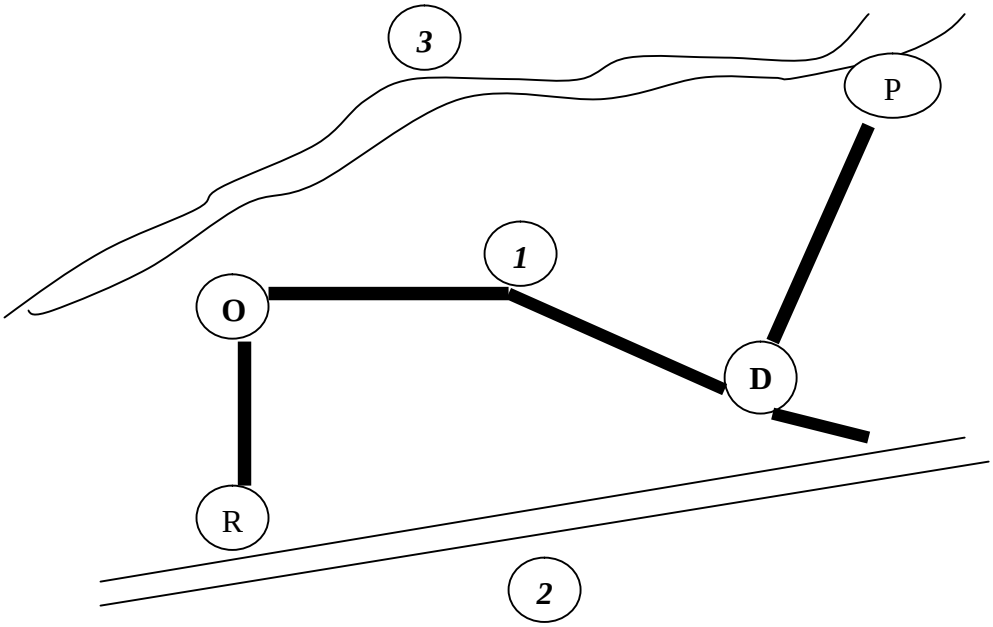
This study will be divided into two distinct parts. The theory will provide an overlook of distribution system's theoretical aspects, as well as of the main aspects of transportation management. It will answer the questions how to determine efficiency of distribution systems, what has to be taken into consideration when talking about economically effective transportation management, what costs categories (internal and external costs, variable and fixed, perceived and actual, direct and indirect, etc.) and performance sides (speed, safety, quality, quantity, frequency, agility) are more important. The second part of theory will be dedicated to describing different modes of freight transportation. It will also represent different views of basic criteria for evaluation of freight movements. The practical part includes calculations of performance of each transportation mode, determining the distance and condition at which it would be more reasonable to implement each mode, as well as analysis and graphical comparison of received results.

A quantitative research method was chosen using different books and articles in the theoretical part. Materials of authors from different countries were used. With the help of discussion from different point of views it is easier to objectively evaluate and compare given alternatives. Practical part is mainly based on the author's own calculations and conclusions. In case of applying different methods of calculations in practical part, the topic would become too wide.

1.1. Background of case company and research

Research was conducted by company OOO NVT, whose consolidation warehouse is located in the Moscow region and distribution centre is situated in Moscow city. The case company was established in 2004 by a group of Moscow entrepreneurs. From the point of dispatch O, which is a consolidation warehouse of the case company, to the point of destination D, which is a distribution centre, during the planning period is necessary to transport a certain amount of cargo. Transportation can be done by one of the three transport modes: road, rail or river (Figure 1).

As was agreed with the case company's representatives, this current scheme can be modified with adding one or two new storages, if it will be reasonable according to main conditions and limitations of the thesis and will be economically efficient (will provide more benefits than losses).



1. Road -
2. Railroad -
3. Water-

Figure 1 Scheme of transport links

The calculation will be provided within three possible options:

1. Deliveries of goods to the railway station R from dispatch point O (warehouse), then transportation by rail to the point of destination D.

2. Transportation of goods by road from warehouse O to distribution point D on the "door to door".

3. Shipping from dispatch point O by the river to the port of destination P, continuing delivery of goods by road from port to the delivery centre D.

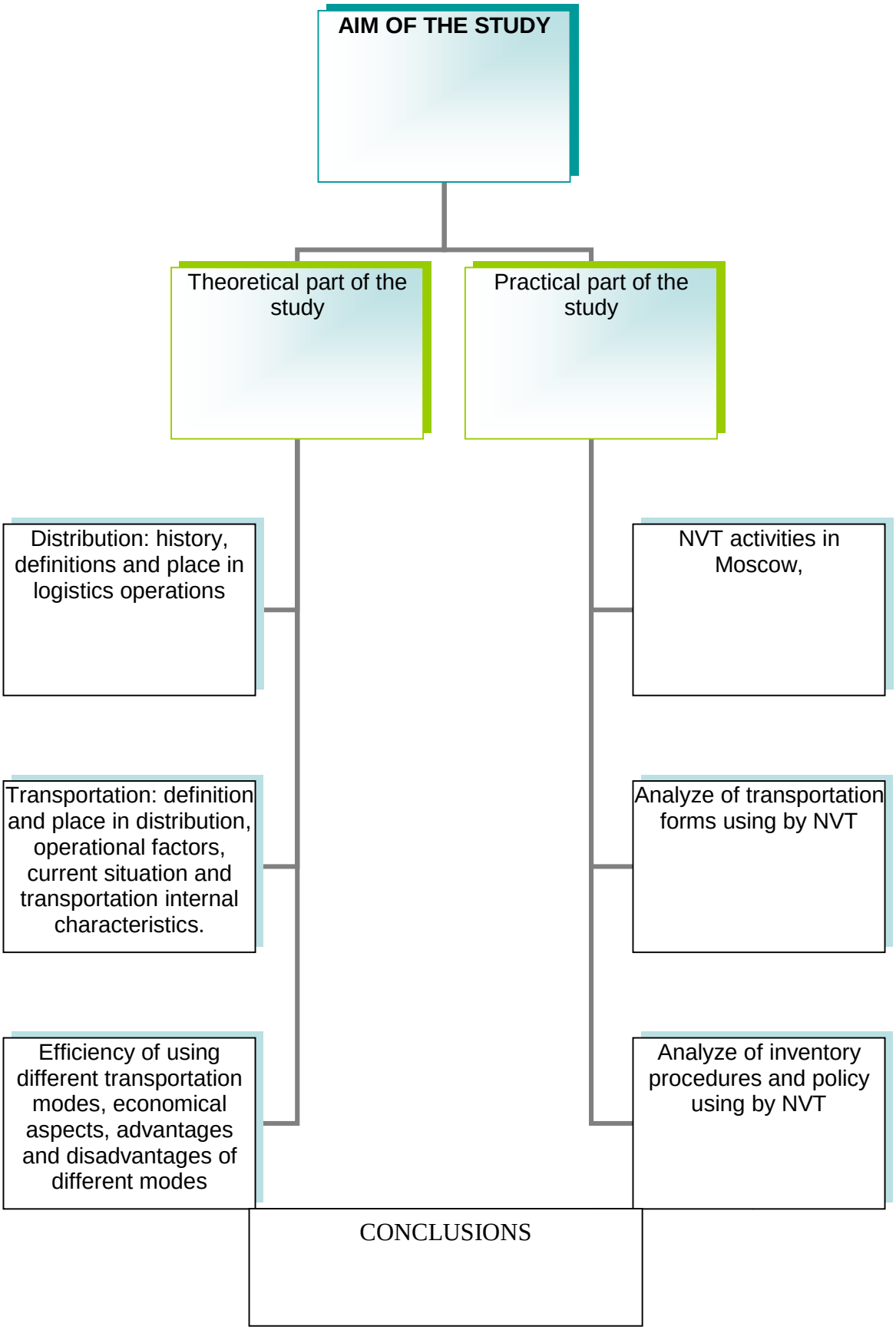
When author has got acquainted to some NVT future basics projects, he realized that one of them could be possibly very useful and comprehensive in many dimensions, both for case company and his personal growth. At first, the name of the project was: Transportation and distribution, own car park versus outsourcing. The authors always wanted connect his professional life with logistics, so that kind of research attracted me immediately. It was like love from at first sight. At the same time it is both reasonably wide and deep, because one can't decide all problems of this huge research without taking under consideration all kind of specific details in regarding to Russian transportation environment nowadays. However, for the University of Applied Sciences this topic was too wide, so it was decided to constrain it by evaluating performance of different transportation modes within case company operations.

Exact salary or other benefits were not agreed, but so far it is clear that premium for that research will consist of certain bonuses, which entirely will be determined by benefits of the study for the case company and Moscow government. Actually, the economic part of this work is not so essential, because the main purpose of this study to pass to action by describing activities, from which will be a lot of benefits and experience despite money. There are a lot of researches, which were conducted in the last few years, when Russia got involved in international cooperation and in process of removing trade barriers in legislation

NVT Wine terminal provides and distributes wine and wine resources for Russian and foreign wine producers. All financial results are under corporative secrecy. Manufacturer has one consolidation warehouse in the Moscow region, with good conditions for savings, and distribution centre in Moscow city. The delivery of goods is possible by implementing three alternatives: road, river and railroad. The following experiment was conducted to determine best possible solution

1.2. Guidelines of the study

According to defined main aims there are the following study guidelines:



2. DISTRIBUTION

Since this work is related to physical movement of the freight, as distribution will be mainly understood and described as physical distribution and its significant parts. The first part of the theory consists of three sections: at first some major aspects in physical distribution system are described. Then proper definition of physical distribution according to later research is chosen.

2.1. History of physical distribution

Dr. Brian Slack maintains that physical distribution is as old as civilization. Even merchants in ancient times had to move goods and raw materials to their destination, and to engage in storage and inventory control. Until the Industrial Revolution, however, these activities were carried out inefficiently (Slack, Rodrigue, Comtois 2006, pp. 218-219).

One of the most acknowledged and a respected persons in the field of physical distribution is British professor Alan McKinnon, who acts as Director of the Logistics Research Centre in London. McKinnon has undertaken research on many different aspects of logistics. According to McKinnon, it is only recently that the full significance and opportunities of physical distribution has been acknowledged in industrial and business circles (Mackinnon 1989). In 1958, for instance, Stacey and Wilson noted that “preoccupation with planning production, purchasing and sales often tends to relegate consideration of the actual movement of finished goods to a secondary role”. To this main purpose of the distribution Satish K Kapoor (2003) added organizing and positing the wide range of human resource in way that increases co-ordination amongst the parts of distribution chain. Insufficiency in those resources in any departments of physical distribution Drucker (1962) understood as one of the major problems over the past years. In 1962 he described distributive functions as “low grade nuisances, accorded little managerial status and assigned less able staff”. (Drucker 1962, p. 225.)

According to Warman (1971), back in past times, warehousing, which is the essential part of physical distribution was often consider to be a “necessary evil”. Not long before that Alexander (1969) described freight transportation as “a dismal calculus of rates and routes”. All that includes in physical distribution was treated as not important to efficiency and profitability and often left without proper and necessary investments. (Kapoor 2003, pp. 233-236.)

However, almost all authors agreed that with the technological revolution, a company was able to produce at a place with production economies and sell the product to a customer in a market with high demand, irrespective of the distance. That, of course, requires proper order system, which could be built easier and more economically efficient than organizing for more comprehensive and quicker movement of the freight. Despite that, Satish K Kapoor defined technical progress as the main reason for increasing physical distance between producers and consumers. Thus, physical distribution is indispensible to any kind of organizations. (Kapoor 2003, pp. 233-236.)

According to Mackinnon (1989) in the end of previous century, firs of all managerial attitudes to physical distribution have changed. From “*necessary evil*” distribution became one of the major cost centre, a significant marketing tool and comprehensive determinant of economic success (Mackinnon 1988). Not so far before Edwards concluded that there is much greater of the fact that the “processes of manufacturing and distribution are complementary” and “that unsold product, however, efficiently produced, is a waste of resources and money. (Mackinnon 1989.)

Satish K Kapoor (2003) sees a huge problem in great amount of function for physical distribution in traditional form of organization. According to this form, the structure is constructed around three basic functions – finance, operation and production, and marketing. Therefore division of physical distribution has to serve all those three “heads”, which lead in overlapping of functions. As you can imagine, production department usually likes to minimize by having long runs, sending as much as possible out to the depots. Almost in the same direction thinks sales department, which prefers to have a high stock, in the time of high

demand, and certainly never run out of stock. On the other hand, finance and control department likes to reduce costs all round, and reduce the amount of investments to maintain increasing requirements of new stocks. This over-lapping in tasks often leads to conflict in the organization. (Kapoor 2003, p. 238.)

Another essential change has happened in role of managers in distribution department. In many firms they are on equal terms with their counterparts in production, marketing and finance. There were several significant changes in managerial and conceptual theories, which lead to different reforms in distributional structure of the organization. Those reforms have radically changed balance between stockholding and movement of freight, as well as in priority in physical distribution functions. (Mackinnon 1989.)

According to MacKinnon (1989) several attempts have been made to identify the factors that triggered the revolution in physical distribution. This revolution could be seen within the context of long term economic development. (Mackinnon 1989.)

La Londe and Dawson (1969) were the same opinion that physical distribution could be treated as the key element in marketing strategy. However, they complain that majority of the firms were primarily concern on their promotion and merchandising of the goods, than about their distribution. Continuing this thought, Stewart writes, that period of recession in the late 1960s, awakened firms to need to control costs and raise efficiency, and with insufficient possibilities of marketing and promotion, distribution left as the “frontier of the costs reduction”. (MacKinnon 1989.)

Mackinnon (1989) added that distribution was also becoming more significant and comprehensive aspect of the firms’ development strategy, because the costs of transport, warehouse and stockholding were rising relative to the costs of the other industrial inputs. On the other hand, manufactures had to respond new structural changes in wholesaling and retailing, by modifying their distributional chain. (MacKinnon 1989.)

Nowadays efficiency of physical distribution is not used at full capacity, and it's easier to find some saving opportunities in distributional department, than in promotional and marketing departments. Currently, computerization is performing the major functions of physical distribution management, from long-range strategic planning to day-to-day logistics, inventory, and market forecasting. The best of these systems are tightly integrated with inventory and other logistics systems, and may even be linked to customers' systems, as is the case with efficient consumer response (ECR) systems. (Slack, Rodrigue, Comtois 2006, pp. 224-227.)

2.2 Definition of distribution

It is only in the last 20 years or so that the concept of physical distribution has emerged and developed into separate management function. Mossman and Norton in 1965 defined physical distribution as "the operation which creates time, place and form utility through the movement of the goods and persons from one place to another". Most of the authors defines place for physical distribution as follows:

Distribution management = *Physical distribution* + Distribution Channel

Like many other new business concepts, physical distribution also originated in US. According to US- authors physical distribution aims at seven R's: the Right product, in the Right quantity, in Right condition, at the Right time and Right place, for the Right customer at the Right cost.

Charles A. Taff (1978) defines physical distribution as management of movement, inventory control, protection and storage of raw materials and processed or finished goods to and from the production line. American Management Association (1966) thinks that physical distribution mainly covers movement of the finished goods from manufacturer to the end customer. On the other side, David J. Bowersox in 1968 defines physical distribution, not only as

action, but also as responsibility to design and administer system to control raw material and finished goods flow. (Bowersox 1968.)

The National Council of Physical Distribution Management (NCPDM), direct that this movement has to be efficient. The structural elements of physical distribution systems are:

- Transportation
- Storage
- Material handling
- Information processing. (Bloomberg, Lemay, Hanna 2002.)

Slack (2006) sees physical distribution concerning with inventory control, as well as with packaging and handling. Customer relations, order processing, and marketing are also related activities of physical distribution. (Slack, Rodrigue, Comtois 2006, p. 234.)

According to Jean-Paul Rodrigue in a broader sense distribution systems are embedded in a changing macro- and microeconomic framework, which can be roughly characterized by the terms of flexibilization and globalization:

- Flexibilization implies a highly differentiated, strongly market and customer driven mode of creating added-value. Contemporary production and distribution is no longer subject to single-firm activity, but increasingly practiced in networks of suppliers and subcontractors. The supply chain bundles together all this by information, communication, cooperation, and, last but not least, by physical distribution.

- Globalization means that the spatial frame for the entire economy has been expanded, implying the spatial expansion of the economy, more complex global economic integration, and an intricate network of global flows and hubs.

Rodrigue (2006) determines main properties for efficiency of distribution system:

- **Distribution time**, notably the possibility to set very specific requirements for deliveries and a low tolerance for delays.
- The **reliability of distribution** measured in terms of the availability of the ordered goods and the frequency at which orders are correctly serviced in terms of quantity and time.
- The **flexibility of distribution** in terms of possible adjustments due to changes in the quantity, the location or the delivery time.
- The **quality of distribution** concerns the condition of delivered goods and if the specified quantity was delivered. (Slack, Rodrigue, Comtois 2006, p. 237.)

Next we will describe place of transportation in physical distribution systems, as well as factors which have to be taken under consideration when one is talking about efficient movement of the goods.

3. TRANSPORTATION EFFICIENCY

Almost all authors define transportation costs as most significant element in common logistic costs. Next author will make a review of most known transportation definitions, describe current situation in transportation market, as well as determine some major transportation characteristics and external and internal features for its efficiency.

3.1. Definition and place of transportation

Ronald H. Ballou (1999) keeps transportation as the most important single element in logistics costs for most companies. Thus the logistician needs a good understanding of transportation matters. Later, Ballou describes importance of an effective transportation as system which contributes to greater

competition in the market place, greater economies of the scale in production, and reduced prices for goods. (Ballou 1999, p. 640.)

David Bloomberg (2000) defines transportation system as the planning, implementation, and control of transportation services to achieve organizational goals and objectives. Where one a traffic manager controlled the modes of transportation, the integrated logistics manager now realizes that control. Thus, the integrated logistics manager must understand transportation operations (Bloomberg, Lemay, Hanna 2002.)

Claude Comtois (2006) determines freight transportation as the process of conveying different types of goods from one point to another using a variety of transport modes. The transport of freight can involve road solutions, routing alternatives and even the use of external organizations to move the freight from a point of origin to a destination. (Slack, Rodrigue, Comtois 2006, p. 251.)

Ballou (1999) sees efficiency of the transportation system as difference between “developed” nations and “developing” one. For Russia this transportation problem is greater than it is discussed officially. (Ballou 1999, p. 661.) For example, it is more economically effective to fly by international air company to Japan from Moscow, and then ride back to Siberia, than take a straight flight using Russia domestic air operator. Another alternative in this case would be railway trip, which usually takes approximately 3 weeks.

What kind of benefits exactly brings inexpensive and efficient transportation?

According to Ballou (1999) with a poorly developed transportation system, the extent of the market is limited to the areas immediately surrounding the point of production. Unless production costs are extremely low compared with those at the second production point – that is, the production costs difference offsets the transportation costs of serving the second market – not much competition is likely to take place. However, with increasing efficiency of transportation system, delivery costs in distant markets can be competitive with other products selling in the same market place. Not to mention, that the goods from outside a

region have stabilizing effect on prices of all similar goods in the marketplace. (Ballou 1999, p. 636.)

Bloomberg (2002) even sees transportation management dominating logistics in the past. In his opinion before transportation services were often purchased, and so the costs were both significant and highly visible. As managers get acquainted with growing significance of other physical distribution costs, like inventory carrying costs, transportation no longer represent all of logistics. (Bloomberg, Lemay, Hanna 2002, p. 136.)

Ballou (1999) suggests not forgetting about economies of scale. Wider markets can result in lower production costs. With the greater volume provided in the market, more intense utilization can be made of production facilities and specialization of labor usually follows. Ballou adds that inexpensive transportation also permits decoupling of markets and production sites. This provides a degree of freedom in selecting production sites so that production can be located where there is a geographic advantage. For example, auto parts manufactured in such places as Taiwan, Indonesia, South Korea, and Mexico are used in assembly operations in the United States and are sold in the U.S. marketplace. Low labor costs and high-quality production are the attraction to manufacture in these foreign locations. (Ballou 1999.)

All previous authors are of the same opinion that the main criteria of efficient transportation is it inexpensiveness. Another argument for it is that inexpensive transportation also contributes to reduced product prices. This occurs not only because of the increased competition in the marketplace but also because transportation is a component cost along with production, selling, and other distribution costs that make up the aggregate product cost. As transportation becomes more efficient, as well as offering improved performance, society benefits within an increasing standard of living. (Bloomberg, Lemay, Hanna 2002, p. 224.)

3.2. Current situation in the market of transportation

Alan Rushton “Handbook for Logistics and Distribution” (2006) draws particular attention on changing nature of physical distribution: particularly fact, that moves by many companies toward global operations, has had an obvious impact on the relative importance of the different modes of transport. According to Rushton, more products are moved far greater distance because companies have developed the concepts of focus factories, with a single global manufacturing points for certain products, and the concentration of production facilities in low cost manufacturing locations. Thus Rushton concludes that nowadays long-distance modes of transport have become much more important to the development of efficient logistics operations that have a global perspective. All of these changes serve to emphasize the need to understand the particular advantages and disadvantages of the different freight transport modes. (Rushton 2006, p. 323.)

According to Tioga (2009) group a high-quality transport infrastructure is conditional to a well functioning economy and society. It determines the competitiveness of production locations, the quality of life and general well-being. Worldwide, industrialized and developing nations depend on efficient freight transportation for internal distribution of goods and for growing trade with the rest of the world. In its final report for southern California of Governments Tioga group prove the fact, that efficient transportation is a critical ingredient in globalization of the world’s economy with following arguments:

- An estimated 10% of the working population is involved in ordering, handling, and moving freight shipments.

- In year 2008 total freight transportation revenues were about $662 billion.

- Freight transportation accounted for the equivalent of 7.2% of Worlds Gross Domestic Product (GDP) in 2008. (The Tioga group 2009, p.2).

One of the main conclusions of above mentioned report was, that freight transportation modes selection has a critical importance to many companies in terms of achieving high customer service level, cost savings and efficiency in the overall supply chain. On the other hand, providers of freight transportation services have been interested in finding out the salient freight transport selection factors of shippers in order to be competitive within freight transport market. Such an attempt would help the freight transport providers to design their marketing mixes effectively. These facts have directed the attention of transport and logistics researchers towards the issue of freight transportation selection since the beginning of 1970, and as a result of this, many empirical researches and reviews have been realized. (The Tioga group 2009, p.4.)

Tioga group concludes that efficient freight transportation is critical to a healthy economy:

- Freight transportation typically accounts for 12-15% of the value of finished products

- Manufacturers and other shippers rely on efficient freight transportation to obtain raw materials and to compete in distant markets

- Wholesalers, retailers, and other receivers need efficient freight transportation to obtain and distribute goods economically, on time, and in proper condition

- Consumers rely on efficient freight transportation for everything from the necessities of life to the purest luxuries. (The Tioga group 2009, p.4.)

That is why Moscow region needs an efficient freight transportation system to compete in Europe and global markets.

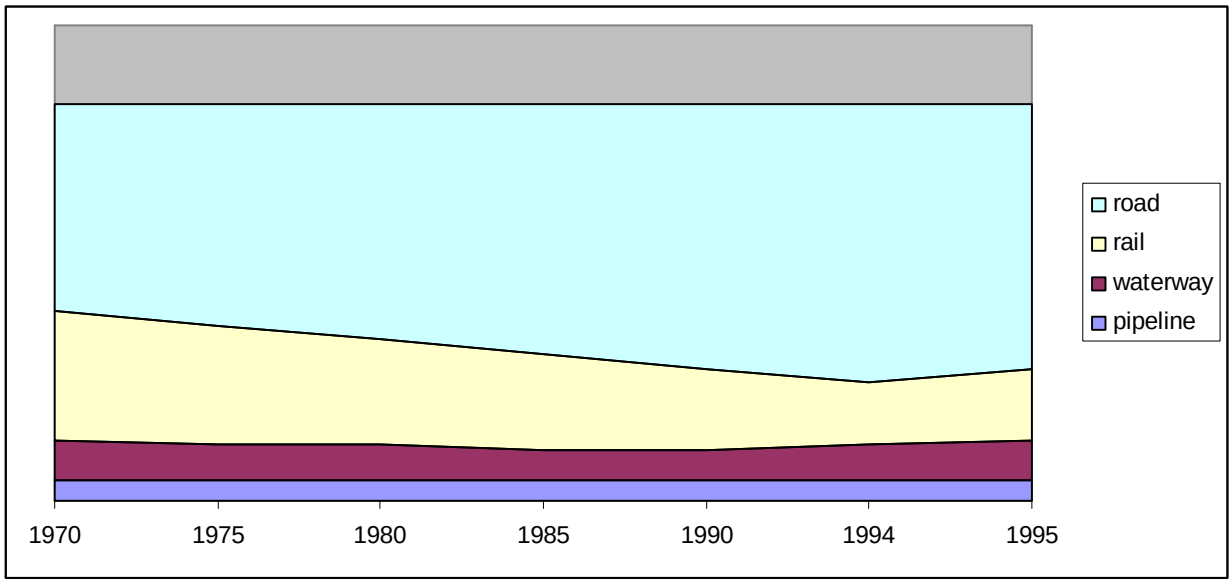


Figure 2 Importance of different transportation modes in Moscow region (Nazarenko 2005, p. 138).

In Russia, where case company mainly operates, road freight transport continues to be the dominant mode of transport. Same mode is broadly represented nowadays in Europe physical distribution system. A look at recent statistic confirms this. The upward trend in the use of road transport has continued for many years but there is now an indication that this may have reached a top, although it seems unlikely that the importance of road freight transport will actually diminish in the future. Rail freight has been declining for many years, but is now become stable. Inland waterways are still important. The use of pipeline has continued for certain specialized movements. Figure 2 indicates the relative importance of the different modes for freight transportation in Moscow region (Nazarenko 2005, p. 138).

Concluding all above mentioned the selection of the most appropriate transport mode is thus a fundamental decision for international distribution, the main criterion being the need to balance cost with customer service. There are very

significant trade-offs to be made when examining the available alternatives between the different logistics factors and the different transport modes.

To choose the most proper transportation mode for our freight, proper evaluation criteria should be chosen first. In the next chapter the most significant evaluation criterias are presented.

3.3 Operational factors for efficient transportation

Rushton (2006) categorizes those criteria to: operational factors, customer characteristics, physical nature of the goods, and finally company's distributional system characteristics. Operational factors in transportation can be divided into external and internal to direct distribution- related factors. In fact, external factors have greater influence on the whole physical distribution system. These are particularly relevant when contemplating the international context of modal choice because from country to country these factors can vary significantly. (Rushton 2006, pp. 328- 330.)

According to Rushton (2006) external factors include:

- basic infrastructure;
- trade barriers (customs duty, import quotas, etc);
- export control and licenses;
- law and taxation;
- financial institution and services, and economic condition (exchange rate stability, inflation, etc);
- communication system;
- culture; and
- climate. (Rushton, 2006 p.335).

This list can be a long one, and the relevant inclusion will vary according to the country under consideration. The particular customer characteristics may also

have a significant effect on the choice of transport mode. Most of the characteristics will need to be considered for both national and international modal choice, that is, they are not specific to overseas distribution. For the Moscow region the main characteristics to take into account are:

- service level / type of service location
- delivery point constraints (access, equipment, etc);
- after- sales service needs;
- credit rating ;
- terms of sale preference (CIF/FOB)
- order size preference;
- customer importance; and
- product knowledge.

>From the modal choice standpoint, these characteristics can be classified into two broad areas: those related to customer service (speed, reliability, etc) and those related to physical attributes (order or drop size, location, delivery constraints, etc) (Rushton 2006, p.337).

Rushton (2006) draws attention to the physical nature of the product, which can be important in determining modal choice as it is with all the other logistic function. The main factors that need to be considered include:

- *Volume to weight ratio* concerns the relative amount of cubic capacity taken up by a given weight of product. For example, one ton of paper tissues takes up far more space than one ton of bricks. This is relevant when considering the different charging structures of the different transport modes – whether charged by weight or by cubic volume.

- *Value to weight ratio* takes into account the value of the product to be transported. The relative transport cost of a high value, low-weight product is likely to be so insignificant to the overall value of the

product that the choice of the mode from a cost perspective is irrelevant.

- *Substitutability (product alternative, etc)* – whereby if a product can be substituted by an alternative from another source, it may be worth while using a fast but expensive mode of transport to ensure the order is accepted by the customer. Where no substitute is possible, a slower and less expensive mode can be used.

- *Special characteristics (hazard, fragility, perishability, time constrains, security)*. A hazardous product may be restricted in how it is allowed to be transported (e.g. some chemicals), and a time –constrained product may have to be moved on a fast and expensive mode of transport to ensure it does not miss its time deadline (e.g. newspapers and promotional products). (Rushton 2006, p.337.)

Finally Rushton (2006) sees increasing influence of the case company distribution structure, when question of the proper transportation mode is taken into consideration. These may be fixed and unchangeable, and seen as sacrosanct by certain sections of the company. There may be subject to change – providing overall benefits can be identified from any change. These factors need to be known. There is no point in designing a system or choosing a mode that fails to allow for these other factors. It is important to be aware of the constrains, that any factors impose on any newly devised system, as the cost implications may well indicate that a trade- off would produce a better overall solution. (Rushton 2006, p.340.)

According to distributional system of case company NVT, those main characteristics include:

- product locations;
- supply points;
- warehouse and storage facilities;

- own transport;
- marketing plans and policies;
- financial situation; and
- existing delivery system.

Despite external criteria there are a lot of factors related to exact transportation modes. Next most significant of them are described.

3.4. Internal characteristics of transportation

Devid Frederick Ross (2000) «Distribution: Planning and control» defined a number of performance characteristics that shippers must consider when selecting the appropriate mode of transportation. These characteristics must be matched with the type and quantity of product to be shipped, the capacities and capabilities of the transportation mode, and relevant cost issues. (Ross 2000, p. 590-592.)

According to Ross (2000), there are six transport mode performance characteristics (Figure 3) living any transportation selection decision:

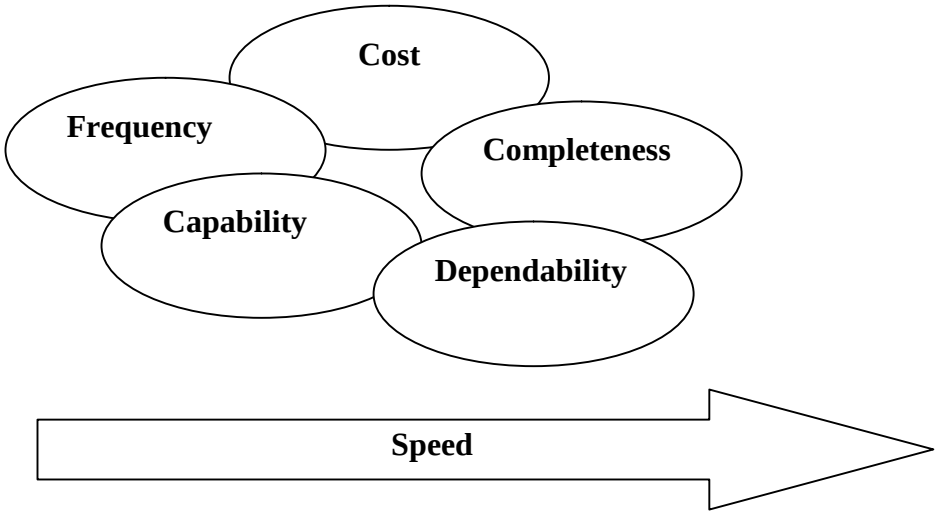


Figure 3 Transportation internal characteristics (Ross 2000, p. 590-592).

1. *Speed.* The ability to transport product from one point in the distribution pipeline to another as quickly as possible is, by far, the fundamental performance characteristic of transportation. Speed provides the marketing utility of time to distribution and ensures place utility. In detail, the speed of any given transport can be defined as the time required to move product from the production source to a terminal, load the product onto the transportation vehicle, traverse terminal point, and deliver the products to the receiving terminal. (Ross 2000, p. 590-592.)

2. *Completeness.* These performance characteristics refer to the ability of the transport mode to move inventory from one location to another without the use of other modes. This is critical because the less material has to be handled between the point of origin and the point of destination, the lower the transport cost and the shorter the delivery time. For example, if material was shipped by rail and the company did not have a rail siding, a second mode, most likely motor carrier, would have to receive the load from the rail carrier, and then transport it to the company where it would have to be unloaded again for final receipt. (Ross 2000, p. 590-592.)

3. *Dependability.* The degree of transport dependability is measured by the performance of a given mode in meeting anticipated on time of delivery. Dependability is critical in ensuring that planned inventory availability to meet place utility is realized to schedule. Poor dependability adds cost to the enterprise in the form of excess inventories and poor customer service. (Ross 2000, p. 590-592.)

4. *Capability.* Capability refers to the ability of a given transport mode to accommodate a specific transport load. The driving factor is the nature of the product. Characteristics such as product type (liquid, solid, bulk, or package), the weight and dimensions, and the load size will have an

effect when deciding on the necessary capabilities of material handling equipment and mode of transport. For example, when moving liquids, tank cars and pipelines would be the most appropriate methods of transport. (Ross 2000, p. 590-592.)

5. *Frequency.* This performance factor is a measure of the frequency a given transport mode can pick up and deliver. Generally, the shorter the transport interval the greater the flexibility of the mode to respond to channel requirements. More frequent transport also decreases the required modal size and the magnitude of the inventory to be transported. (Ross 2000, p. 590-592.)

6. *Cost.* Although market time and place utilized are critical elements of transport mode selection, the costs in transportation. The most obvious costs is the rate paid to the carrier for use of the mode itself. Other indirect costs are labor and material handling to load and unload the carrier, occurrence of spoilage and damage, insurance to protect against possible loss, and in-transit inventory carrying costs paid by the shipper. (Ross 2000, p. 590-592.)

4. EFFICIENCY OF USING DIFFERENT TRANSPORTATION MODES

The interaction of different transport modes is coherent and coordinated work of transport in total transportation process. This cooperation depends on many conditions, legal, economic, technical, technological, organizational and managerial issues.

4.1. Diversity of transportation modes

According to McKinnon, the selection of freight between transport modes, often called modal split, has been one of the most controversial topics in the field of transport logistics. McKinnon thinks this is because modal choice decisions are

not always based upon a full and rational appraisal of options available. (McKinnon 1989.)

Kent (1988) assumed that modal choice is influenced by three main factors: price, speed and reliability. Parker (1988) thinks that a country's or a region's freight modal interaction is also depend on a range of other factors, such as its physical geography, the spatial distribution of its population and industry, the density of its transport networks, the structure of its economy and governments' policies on transport regulation, investment and taxation. Both have the same opinion that a choice of transport mode has a direct impact on the efficiency of a physical distributional channel. Each transport mode possesses different characteristics, different strengths and weaknesses, threats and possibilities. (McKinnon 1989.)

McKinnon defined three main bases for transportation mode choice: According to the first one that choice is dictated by economic cost variables. The second type of model assumed that modal choice is based on relationships between physical aspects of the transport system (e.g. speed, frequency) and physical aspects of the product. (McKinnon 1989.)

According to McKinnon, finally, there are models that are based on decision-maker or human perception of each mode of transport or combination of modes. Employee own perceptions do determine whether or not a particular mode will be used. McKinnon thinks that the process of selecting the appropriate mode is dependent upon a variety of service attributes. (McKinnon 1989.)

Slack (2003) thinks that the use of transport modes depend on the type of product transported and the availability of modes. Apart from the direct cost of transport, which can be high, especially for complex movements, the cost of tied inventory is often critical in the case of high value products in the physical distributional process. (Slack, Rodrigue, Comtois 2003.)

For the reason that in our case author compares only road, railway and river transportation alternatives, next author will describe only those three modes more precisely, as well as the economic aspects of each one.

4.2. Economical aspects of different transport modes.

According to Nazarenko (2005) the majority of freight transportation is executed with the help of two or more transportation modes. For example 80 per cents of cargos, which arrive in Russian ports, are transported then by railroad. Points of interaction are also known as transportation crossings. Previously those crossings, because of its historical development, institutions, private ownerships, geography, topography, built without a rapid transition of cargo from one mode to another. Transit passengers made new documents to transport goods. The goods overloaded in these crossings. Only with the introduction of mixed direct interaction to the owners of the goods were released from liabilities to reload goods. (Nazarenko 2005, p. 147.)

Nazarenko (2005) represents some main economic aspect of transportation as follows:

1) Development of common freight planning (annual, operating on the quarter, month), which allows to prepare in advance rolling stock or reserve it. This is especially important when goods transferring from railroad to sea transport, where often great delays appear.

2) The establishment of agreed rates for the carriage on different types of transport. It has to be created as system of common tariffs, which encourage customers and transportation providers to multimodal transport.

3) The introduction of a unified common nomenclature of goods, development of unified planning and reporting data; economic indicators characterizing the

quality and efficiency of freight transportation should be unified. (Nazarenko 2005, p. 150.)

Despite the growing importance of water transportation Dr. Jean-Paul Rodrigue (2003) sees not f implemented potential of two major land modes, roads and railways. Obviously, roads were established first, as rail technology only became available by the 18th century, in the midst on the industrial revolution. Historical considerations are important in assessing the structure of current land transportation networks. Modern roads tend to follow the structure established by previous roads, as it was the case for the modern European road network (especially in Italy, France and Britain) that follows the structure established by the Roman road network centuries before. (Slack, Rodrigue, Comtois 2003, pp. 345- 352.)

As already indicated, road freight transport is the most important mode within Europe. In the context of international distribution, road freight transportation is also important, particularly to and from the Russia in terms of the use of roll-on, roll-off (RORO) ferry services through Finland and Baltic countries. This form of transport consists of the through transport of goods from factory or warehouse direct to customers' premises abroad.

4.3. Advantages and disadvantages of compared transport modes

First of all, it is has to be mentioned that the railroad transport plays very significant role in freight processing in Russia nowadays. Nazarenko (2005) explained this fact by many reasons. Above all, this mode of transportation is relatively cheap. The usage of the huge railroad trains gives an advantage that it is possible to carry completely different kinds of goods by one single train due to the existence of different types of cars (normal cars, semi-cars, refrigerators, platforms, cisterns, post-cars, cars for chemical production, etc), which gives a distinct advantage over strictly specialized vessels and road vehicles (not to

mention long-haul tractors, to which can be attached different types of trailers). (Nazarenko 2005, pp.187-188.)

Russian scientists Bildman and Prochorov (2000) think that ecological advantage by railroad transport is obvious. Use of electric locomotives has a small environmental impact. Bildman and Prochorov initiated the experience to measure and compare ecological influence for different transportation modes. Pollution effective from one single locomotive within transportation, for example, of five- kilometer train cars can not be compared with pollution caused by five kilometer of tracks. At the same time railroad transport uses less human resources in delivery of goods. Only two persons can lead the train in any point. Therefore amount of cargos, transporting in account per one person, which is employed in this process, immeasurably greater than that in road transport or sea vessel (crew of medium-size ship, more than 10 people, usually 12-15). Rail is by far the land transportation mode offering the highest capacity with a 23,000 tons fully loaded coal unit train being the heaviest load ever carried. (Bildman, Prochorov 2000, pp. 9-18.)

The main disadvantages of railroad transport are:

- The necessity for building of special rails.
- Expensiveness of manufacturing and building rails.
- Necessity to build specialized buildings and facilities for loading / unloading, maintenance, and repair.

According to Comtois (2003) the use of river transport, where possible, is much cheaper than other modes of transportation. Using natural waterways large volumes of cargo can be carried. River transportation has high terminal costs, since port infrastructures are among the most expensive to build, maintain and improve. High inventory costs also characterize maritime transportation. More than any other mode, maritime transportation is linked to heavy industries, such as steel and petrochemical facilities adjacent to port sites. (Slack, Rodriguez, Comtois 2003.)

The most mobile and most convenient, especially for small operations on short and medium distances is road transport. At the same time it is the most expensive, less environmental friendly and wasteful.

The main advantage of road transportation is low level of physical limitation. However, Rodrigue (2003) sees physiographical constraints, as significant in road construction with substantial additional costs to overcome features such as rivers or rugged terrain. Road transportation has an average operational flexibility as vehicles can serve several purposes but are rarely able to move outside roads. Road transport systems have high maintenance costs, both for the vehicles and infrastructures. They are mainly linked to light industries where rapid movements of freight in small batches are the norm. Yet, with containerization, road transportation has become a crucial link in freight distribution. (Slack, Rodrigue, Comtois 2003.)

Slack (2003) adds to advantages of road transport mode, the fact that the car is practically requires no special handling facilities, and due to its mobility allows delivering the goods directly "to the door of the customer". Therefore, there is no need to transfer operations from cars to other modes of transport. (Slack, Rodrigue, Comtois 2003.)

Finally all authors agreed that it is better to concern a variety of modes used in combination so that the respective advantages of each mode are better exploited. Although intermodal transportation applies for passenger movements, such as the usage of the different, but interconnected modes of a public transit system, it is over freight transportation that the most significant impacts have been observed. Containerization has been a powerful vector of intermodal integration, enabling maritime and land transportation modes to more effectively interconnect.

5. METHODS OF CALCULATION FOR DIFFERENT TRANSPORTATION MODES

5.1. Formulas and description of experiment

Monetary expression of experiment's operating costs, as well as material means and resources used during transportation, need to be calculated as follow:

$$\text{Total Costs} = \text{Operating costs} + \text{ROI} * \text{MMI} \quad (5.1)$$

Where:

1. Operating costs are ongoing operating costs measured in roubles;
2. ROI = 1, 15;
3. MMI - the capital invested in processes related to transport mode, measured in roubles.

Material means and resources has to be multiplied by percentage Return on Investments, because the same amount of money can be used on the other means, for example landing to bank, invested in alternatives project or spent on current needs of the case company. As this formula could be divided on three parts each one has to consider more precisely to define consist of them.
Next we will analyze how exactly each part of above described formula was formed.
For road transport operating costs calculated as follow:

$$\text{Operating costs} = TC * D * AVT \quad (5.2)$$

Where:

AVT – The annual volume of transportations, tons;

TC - Cost of transportation roubles/ 1 ton / km, which includes, for example, fuel, repair, depreciation, driver salary, etc. and,

D – Distance of transportation, km.

Since chosen transportation mode will be used in long perspective, as well as volume of each mode varies largely, for example, one river vessel in comparison to one track. To equal the performance of transportation modes author decided to analyze it according to year amount of transportation and created AVT-parameter. It is also reasonable to make, because such decisions has to be taken in long -term view, as there are certain switching costs to transfer from one transportation mode to another every time when such a need occurs.

For rail and inland waterway transport the following calculation has to be implemented:

$$\text{Operating cost} = AVT * (TC_d * D_d + TC * D + TC_e * D_e) \quad (5.3)$$

where:

AVT - the annual volume of transportations, tons;

$TC_{delivery}$, $TC_{exportation}$ - cost of 1 ton / km, respectively, in the delivery of cargo by road to the main transport (d) and exportation it to the point of destination (e), roubles / ton / km;

TC - the cost of transportation of cargo transportation, roubles / ton / km;

D, $D_{delivery}$, $D_{exportation}$ - distances, respectively in the delivery distance to main transport (d) and exportation from main transport to point of destination, km.

Next, author has to determine the amount of material invested in process of transportation, for example bought trucks, or built or bought additional constructions to loading and unloading. Such costs, as terminal payment in port of destination or delivery, as well as insurance and other payments and charges have to be taken into consideration. On the other hand, the same amount of resources could be possibly invested in other project of land to the bank. Invested capital and resources in circulation MMI are determined as follow:

$$MMI = AVT * t / 365 \quad (5.4)$$

where:

AVT- average value of transportation

t - the average time of delivery, days.

Next average time of delivery has to be determined. Average delivery time is defined as follows:
For the first road version it is relatively easy:

$$T = D/V \quad (5.5)$$

where:
D – Distance of the road transportation, km;
V - the speed of transport by road, km / h.

For the second, railroad option of delivery it is more complicated, because it consists of many different stages:

$$t = t_{delivery} + t_{loading} + t_{transporting} + t_{unloading} + t_{exportation} \quad (5.6)$$

where:
$t_{delivery}$ - time delivery of goods by road to the railway station;
$t_{loading}$ - waiting time of loading at the railway station;
$t_{transporting}$ - during carriage by rail;
$t_{unloading}$ - while unloading at the destination.
$t_{exportation}$ – delivery from unloading place to point of destination.

For the third, river option of delivery:

$$t = t_{delivery} + t_{loading} + t_{transporting} + t_{unloading} + t_{exportation} \quad (5.7)$$

where:
$t_{loading}$ - waiting time of loading at the railway station
$t_{unloading}$ - the time of discharge of river vessels and overloading to road transport;
$t_{transporting}$ – during carriage by the river
$t_{exportation}$ – time for exportation of cargo from the river port to destination.

Finally, as one have already understood, the distance for the second and third options of transportation divided on different stages, which have to be handled within a distinguish approach. When and if one may include traffic question in this discussion, it has to be said that capacity problem in ports and overloading of the roads give a lot of bonuses to railroad option of transportation. But, at least nowadays in Russia railroad movement is governmentally monopolized, and as there is no competition, the real conditions and quality of services in railroad remain very poor. This governmental aspect will not be mentioned more than that, but in any case it has to be acknowledged, that there are no huge differences between transportation modes according to existing delays.

Because each option of transportation has different capacity or amount of cargo that could be transported by one shift, we decided to conduct our research based on the amount of transported cargo by year which is approximately 1200 tons. Despite above described we have conducted an additional data for each option of transportation, including: average speed, amount of transported cargo, distance, time for unloading, reloading, loading in terminals, railway stations and ports, etc.

Next it is shown how each transportation option is calculated.

5.2. Calculation of the first delivery option

According to the first alternative, cargo is delivered to the railway station O' from departure point O, transport by rail to the destination D. (Figure 4)

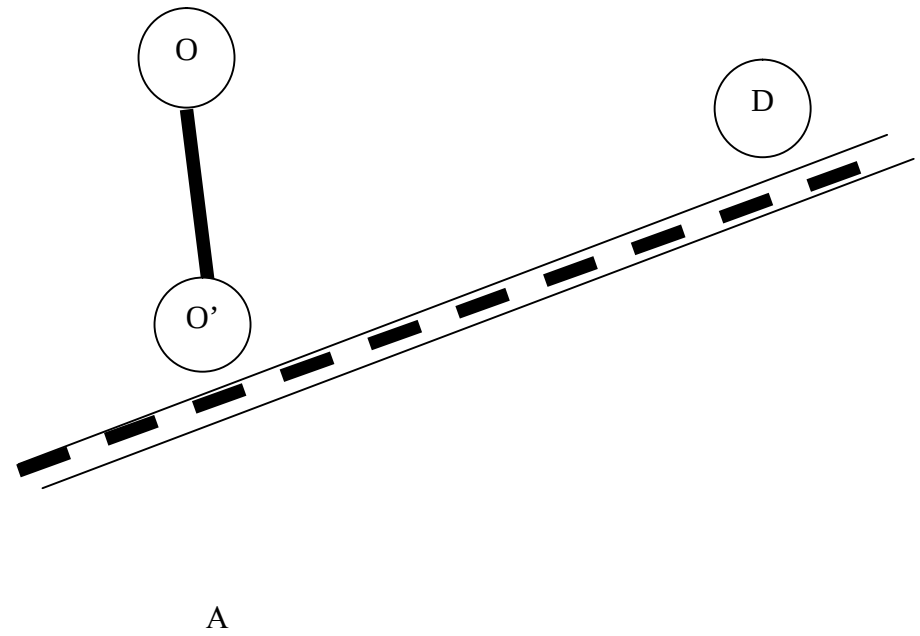


Figure 4 The scheme of delivery according to the first option

Rail transport is a mean of transport and track facilities, providing the movement along the rails. Differ by type of traction: locomotive, diesel locomotive, electric locomotive and the type of rolling stock, based on different types of cargo (passenger car platform, tanker, etc.). In the first option considered the interaction between rail and road (for delivery of goods to the railway station and from railway station of destination to the point of destination)

Initial data for calculating the first option of the transport of goods:

1. average speed of transporting by road from place of unloading to railway station or from railway station of destination to distributional centre 75 km/h;
2. average speed for transport by rail 60 km / h;
3. distance transport by road to the station and from the station to distributional centre 54 km;
4. distance transport by rail 320 km;
5. base costs per 1 ton / vehicles by road (up to 100 km.) – 90 roubles / t /km;
6. base costs of railway transportation over a distance of 300 km (up to 300 km.) – 109 roubles / ton / km;
8. average amount of investments (RI) 16000 roubles / ton;
7. average volume of transporting cargo (AVT) 1200 tons;

Current operating costs are calculated using the following formula:

$$\text{Operating costs}_{\text{railroad}} = AVT * (\text{Base cost}_{\text{delivery}} * D_{\text{delivery}} + \text{base cost}_{\text{transportation}} * D_{\text{transportation}}) \quad (5.8)$$

where:

$\text{Base cost}_{\text{delivery}}$, $\text{base cost}_{\text{transportation}}$ - base cost of 1 ton / km in the delivery of goods by road to the station of departure and accordingly the cost of carriage by rail;

D_{delivery}, $D_{\text{transportation}}$ – distance of transportation by road and relatively distance of transportation by rail.

$\text{Operating costs}_{\text{railroad}} = 1200 * (90 * 54 + 109 * 320) = 47\,688\,000$ roubles

Next author will calculate the amount of material included in this option of transportation:

$$MMI = AVT * RI * t / 365 \quad (5.9)$$

Average delivery time is defined as follows:

$$t = t_{delivery} + t_{loading} + t_{transporting} + t_{unloading} + t_{exportation} \quad (5.10)$$

Where:

$t_{delivery}$ - time delivery of goods by road to the railway station;

$t_{loading}$ - waiting time of loading at the railway station;

$t_{transporting}$ - during carriage by rail;

$t_{unloading}$ - while unloading at the destination.

$t_{exportation}$ – delivery from unloading place to point of destination

Basing on numbers from Appendix 1, average time of transportation is:

$$t = 0{,}015+2{,}3+1{,}2+0{,}13+1{,}8=5{,}445 \text{ days (24 hours)} \quad (5.11)$$

Knowing the average delivery time the amount of materials in circulation can be determined:

$$MMI= (1200 * 16000 * 5.445) / 365 = 286\,422 \text{ roubles} \quad (5.12)$$

The criterion for economic evaluation of the freight's distribution between transport modes is a minimum expenditure of materials and workforce in the delivery of goods from one point to another. Monetary expression of these costs is ongoing (operating) costs, as well as equivalents material during transportation.

The costs of transportation are calculated as follows:

$$\text{Total costs}= 47\,688\,000 + 1{,}15 *286\,422= 48\,017\,385 \text{ roubles} \quad (5.13)$$

5.3. Calculation of the second delivery option

Within the second option of delivery goods are transported by road vehicle from point of dispatch or origin O to point of destination or consumption D (Figure 5).

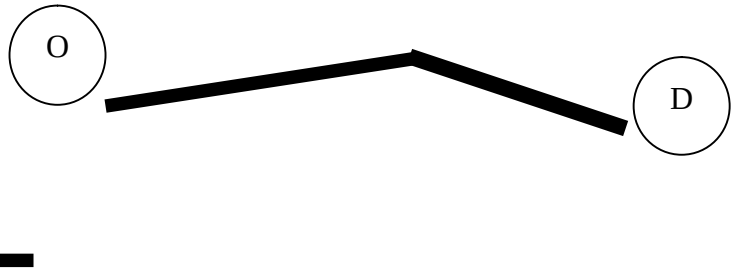


Figure 5 The scheme of the transport relations according to the second option of transportation.

Transportation of goods by road, also defined as delivery "from door to door".
Initial data for calculation of the second option of the transportation:
1. average speed of transport, with direct delivery of car - 60 km / h;
2. distance transport by road (from door to door) - 270 km;
3. base costs per 1 ton / car (up to 300 km.) 156 roubles / t /km;
4. average volume of transportation (AVT) - 1200 tons;
5. average amount of resources invested (RI) 20000 roubles/ ton.
Current operating costs are calculated using the following formula:

Operating costs =156*270*1200= 50 544 000 roubles (5.14)

The amount of capital used or invested in delivery according to second option then will be:

MMI = AVT* RI * T/ 365 (5.15)

Determine the average time of delivery:

T = D/V = 270/60 = 4, 5 hours/24= 0, 1875 days (24 hours) (5.16)

Knowing the average time of delivery the amount of materials used or invested can be determined:

MMI = (1 200 *20 000 * 0, 1875) /365=12328 roubles (5.17)

Total costs of transportation are calculated as follow:

TC= 50 544 000 +1, 15* 9863 = 50 555 343 roubles. (5.18)

4.4. Calculation of third delivery option

According to the third option goods are delivered in the following way:
Goods are transported from point of dispatch A to the port of unloading B', and then cargo is delivered from this port to point of destination by road (Figure 6).

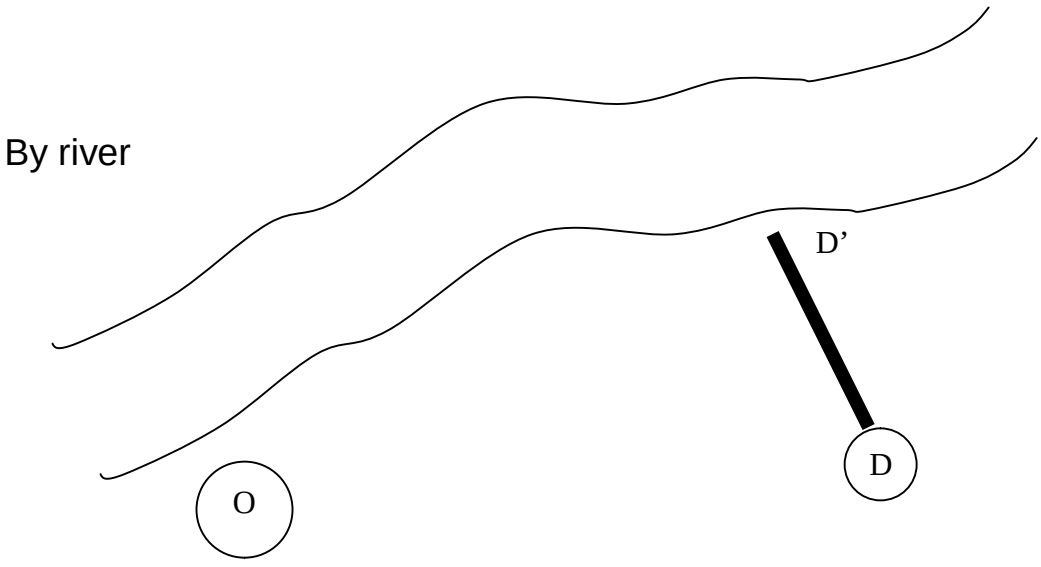


Figure 6 The scheme of transportation (third option of delivery).

Initial data for calculating the third option of transportation:

1. average speed of transportation by road from the port of unloading to point of loading 75 km / h;
2. average speed of the carriage on the river 20 km / h;
3. distance by road from point of dispatch to the port of dispatch and from the port of unloading to the point of destination 72.4 km;
4. distance of transportation by water 210 km;
5. base costs per 1 ton / km transported by road vehicles (up to 100 km.) – 102 roubles / t/km;
6. base costs per 1 ton / km. transported by water (up to 300 km.) – 119 roubles / ton / km;
7. average volume of transportation per year 1200 tons;
8. resources invested for 1 ton of cargo 12500 rub.

Reloading costs are included in road and water transportation respectively. Current operating costs are calculated using the following formula:

$$\text{Operating costs} = AVT * (BC_{\text{by water}} * D_{\text{by water}} + BC_{\text{by road}} * D_{\text{by road}}) \quad (5.19)$$

$$\text{Operating costs} = 1200*(119*210+102*72.4) = 38\ 849\ 760 \text{ roubles} \quad (5.20)$$

The total amount of materials and resources invested or implemented within this option of delivery is calculated as follow:

$$MMI = AVT* AP * t / 365 \quad (5.21)$$

Average delivery time is defined as follows:

$$T = t_{\text{delivery}} + t_{\text{loading}} + t_{\text{transporting}} + t_{\text{unloading}} + t_{\text{exportation}} \quad (5.22)$$

where:

$t_{\text{unloading}}$ - the time of discharge of river vessels and overloading to road

transport;

$t_{exportation}$ – time for exportation of cargo from the river port to destination.

$T_{delivery}$ – 0, 2 days

$T_{loading}$ - 4 days

$T_{transporting}$ – D/V=140/20=7 hours/24=0,292 days

$T_{unloading}$ – 1 day

$T_{exportation}$ - D/V=11, 2/25=0, 45 hours/24=0,019 days

For the third option the whole transportation time will be defined as follow:

T=0, 2 +4 +0,292+1+0,019=5,511 days (5.22)

Knowing the average time of transportation total material usage can be calculated as follow:

MMI = (1 200*12 500 *5,511)/365=226 479 roubles (5.23)

Total costs of delivery according to the third option can be determined as follows:

TC = 38 849 760 +1, 15* 226 479 = 39 110 211 roubles. (5.24)

5.5. Comparison of received results

According to calculations (Table 2) of three possible options, it can be seen from the table that the most appropriate mode of transportation is the delivery by water, as it has the lowest operating costs, as well as a lower consumption of materials and resources than within other modes of transport, but on the other hand the time of transportation is 5.511 days.

№	Performance numbers	Option of transportation		
		railroad	road	river
1	Total distance, km	374	270	210
2	Total time of transportation, days.	5,445	0, 1875	5,511
3.	Average amount of transportation, tons.	1 200	1 200	1 200
5.	Total costs of transportation/ roubles	48 017 385	50 555 343	39 110 211

Table 2 Common table of investigation results of all three option of transportation.

Regardless of the fact that transportation by road is the most expensive: 50 555 343 roubles, it has the shortest time of delivery - 4, 5 hours or 0, 1875 days. Also it is essential to mention that, within the road transportation there is no need to overloading or transferring goods, which could be damageable for them and enhance total costs of transportation.

5.6. Graphical method of determining the appropriate use of transport

The aim of using graphical method is to define the costs on the equivalent distance of D within comparable modes of transport.

Table 3 Comparative costs of transport modes at the same distance.

Distance, km	Basic costs	Volume	Total costs
Road transport			
10	99,9	1200	TC= 10*99,9*1200 =1198800
100	111	1200	13320000
200	123	1200	29520000
300	135	1200	48600000
400	149	1200	71520000
Railroad transport			
10	60	1200	720000
100	96	1200	11520000
200	124	1200	29760000
300	130	1200	46800000
400	135	1200	64800000
Water transport			
10	70	1200	840000
100	83	1200	9960000
200	105	1200	25200000
300	114	1200	41040000
400	123	1200	59040000

Now, with the help of above represented table it is possible to compare all three options graphically.

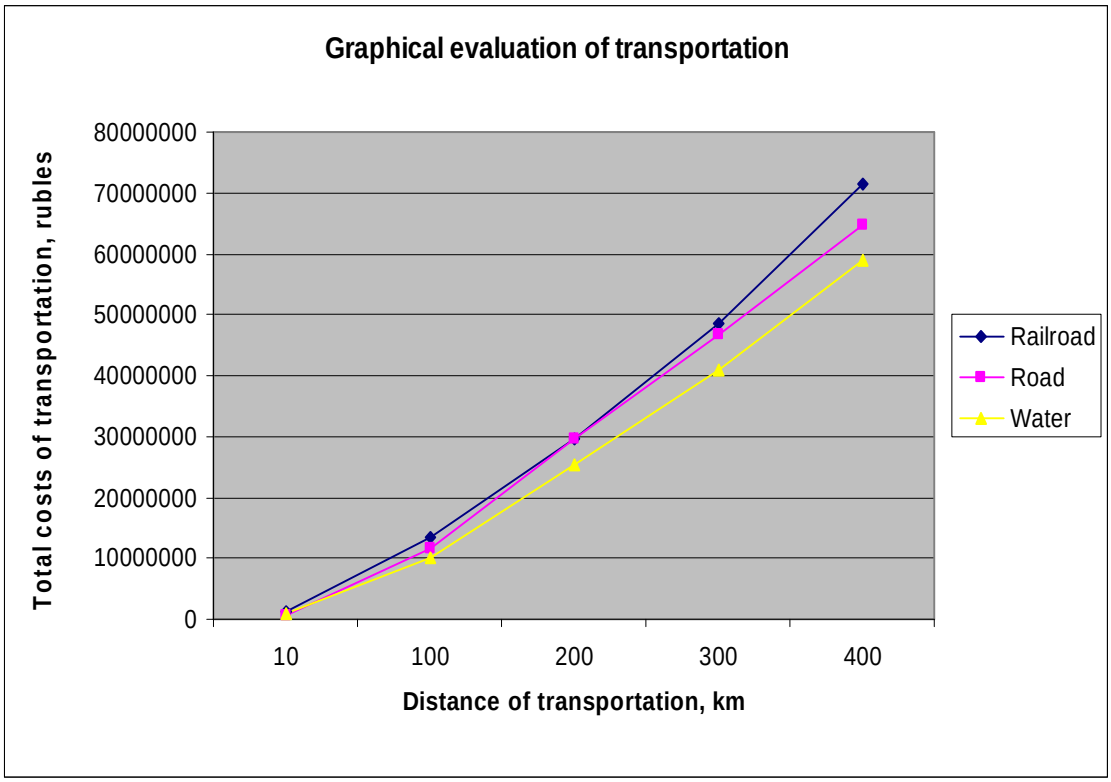


Figure 7 Evaluation of transportation using graphical method

From a graph, we can conclude that approximately at a distance of 150 km costs for all modes of transport are approximately the same based on total transportation costs. When comparing the cost changes at the equivalent distance, as use of rail and road transport, it is clear that the costs of road transport with increasing distance increase, and the railway and river transport reduce.

Regardless of the distance water transportation is still the cheapest, as well as the longest in delivery time. Approximately, at a distance of 250 km the total costs of railway and road transportation are the same. It can be explained that traffic problem in the road option of delivery is compensated by monopoly status of governmental company in railroad transportation.

6. SUMMARY AND CONCLUSIONS

Analyzing the carriage of goods by various modes of transport, it can be seen that:

№	Performance numbers	Option of transportation		
		railroad	road	river
1	Total distance, km	374	270	210
2	Total time of transportation, days.	5,445	0, 1875	5,511
3.	Average amount of transportation, tons.	1 200	1 200	1 200
5.	Total costs of transportation/ roubles	48 017 385	50 555 343	39 110 211

Table 2 Common table of investigation results of all three option of transportation.

Distance of transportation for every mode is different; the shortest distance to overcome in delivery by water transport is 210 kilometers; the largest transportation by railroad is 374 kilometers.

Low-cost form of transport is the delivery by water: a small distance is 210 km. and costs are 39 110 211 roubles, but at the same time the greatest length of time is 5, 511 days.

Transportation by car is the most rational in sense of time, at a distance of 250 km., as well as the least time, 4 hours or 0, 1875days. Costs are relatively low: 50 555 343 roubles. Road transport is preferable in short-distance deliveries, because with increasing distance of transportation current operating costs increase.

State monopoly in railroad transportation, as well as traffic problems in road

transportation were not described. However, approximate time of delivery was calculated within above mentioned issues.

It is appropriate to use the leverage of railroad transport over long distances of deliveries, because costs associated with distance in this mode of transport are less dependent on distance increasing .Traffic aspects were not discussed in this work, as well as the problem with monopoly situation in railroad transportation and river port authorities, because in my opinion their significance on the time of transportation is relatively same.

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APPENDICES

Appendix 1:

Table 1 The distance between points of transportation

Delivery option	Distance, km
1. Road freight (from door to door)	180
2. Rail road transport Delivery by road to railway station and from railway station to point of destination.	6 (4+2)
Rail freight	180
Shipping Shipping by the river	140
Delivery from port to point of destination	11,2