INTERMODAL OPTIMIZATION WITH HARMONY SEARCH

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Abstract: The optimal design or reengineering of supply chains using intermodal transportation is a very important part of the cost effective logistics system. Within the frame of this paper the author focuses on the optimal design of intermodal transportation problems. The first part of the paper shows the most important aspects of European and Hungarian transportation policies and strategies. The second part of the paper describes a possible model of intermodal transportation problems and focuses on a possible mathematical method based on cost functions. The author supposes a possible heuristic solution method, which makes it possible to find the optimal routing for containers using the possible transportation modes.

Keywords: containers, intermodal transportation, modeling, optimization

1. Introduction

Supply chain management trends are related to increasing globalization of economy, transparency and efficiency of demand-driven logistic processes. Agile systems are able to match supply and demand in stochastic market. One of the most expensive logistic operations is the transportation. The reduction of transportation costs of supply chain processes leaded to the appearance of different supply methods. The intermodal freight transport, which means the transportation of products in different intermodal containers reduces the material handling costs, improves the security of products, decreases the transportation time and increases the availability of suppliers. The intermodal transportation uses multiple transportation modes. The optimization of supply chain is a quite wide area, which justify the cooperation of sciences in the field of transportation and operation research to answer the following questions [1]: What problems are given in the field of multimodal and intermodal supply chain to be solved by operation research scientists? What kind of operation research methods and tools can be used to solve the problems?

The design of intermodal supply includes heuristic and metaheuristic techniques [2, 3, 4], linear and non-linear models [5]. The most important topics of the design of transportation systems of intermodal and multimodal supply are the followings: location analysis [6]; optimal routing for intermodal containerized transport [7]; building of loading units; loading and unloading processes and resources; containerization. A very important aspect of optimization of supply chain is the data collection, data relations and the design of optimal database [8].

The legal regulation and background of the optimal design and improvement of intermodal and multimodal transportation networks and supply chain processes is assured by the aid of national and international transportation policies and strategies. The next capture summarizes the most important aspects of the transportation strategies.

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2. European and Hungarian transportation strategy

The globalization of the economy and the appearance of lean philosophy leaded to the increased importance of development of external logistics processes, out of which the transport industry represents the most logistics-intensive systems. The development processes of transportation are controlled by national and international policies and strategies. The transportation policies and strategies depend on the followings: increased gross domestic value; changes in industry structure; export controlled economy; labor supply from the border countries; decreased regional differences. The most important aims of this policies and strategies are the followings: decrease the infrastructural differences of regions caused by transportation related faults; make an end of the bottlenecks of transportation networks; moderate of traffic snarls; balance of different transportation modes; environmental friendly handling of globalized transportation. There are a huge number of development tendencies of logistics, which influence the transportation strategies and policies: decreased production deepness; just in time and just in sequence production and supply; increased importance of make or buy decision; kanban supply; increased outsourcing; improvement of systems and processes by the aid of benchmarking; wide range application of automatized material handling machines and transportation machines. However these logistics related aspects influence the realization on the level of tactics and operation, but the milestones of strategies and policies are almost the same on European and national level. The transportation strategies of nations and Europe have a time interval between 10 and 15 years and cover not only the development of the different transportation modes of passengers and goods, but also focus on the development of regional logistic centers, integrated ticketing systems, city logistics, environmental and social aspects of transportation and transportation related systems and processes.

The European Commission summarized the most important milestones of transportation strategy within the frame of the white paper entitled "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system". This paper focuses on the following important areas of intermodal transportation related topics [9]: growing transport and supporting mobility while 60% emission reduction target is required; an efficient core network for multimodal intercity travel and transport; a global level-playing field for long-distance travel and intercontinental freight; a competitive and resource efficient transport system; modern infrastructure and smart funding.

Why is it important to focus on transportation? The answer is given in the Eurostat statistics: "The transport industry directly employs more than 10 million people, accounting for 4.5% of total employment, and represents 4.6% of Gross Domestic Product (GDP)." Another aspect of work out state of the art strategies for transportation is the fact, that logistics operations (transportation, storage, loading and unloading, packaging, material handling, etc.) account for approx. 20% of the cost of a finished products.

3. Intermodal transportation

The globalization of economy and marketplaces leaded to the growth of intermodal and multimodal logistics. The globalization of the marketplaces is facilitated by the international, regional and global trade agreements. The increasingly importance of

intermodal transportation is closely connected to the development of information and communication technologies.

Intermodal transportation is a secure way of transportation. Up to 20 % of accidents involving trucks can be attributable to inadequate cargo securing, so the European Commission Transportation Department supports the improvement of intermodal transportation[2]. The intermodal transportation is a big business area of logistics. There is a huge number of shipping liner companies (Table I.) with over 500 kTEU[3].

Table I. Shipping liner companies over 500 kTEU in 2012 [10]

Company	**TEU capacity**	**Number of ships**
A.P. Moller-Maersk Group	2 632 681	668
Mediterranean Shipping Company	2 221 631	488
CMA CGM	1 319 722	390
COSCO	699 905	154
Hapag-Lloyd	650 249	149
Evergreen Marine Corporation	645 693	172
American President Lines	616 456	139
CSCL	563 091	150
Hanjin Shipping	541 378	107

The general model of intermodal transportation includes the following processes: containerization[4] of products; transportation of containers from the producer (source) to the harbor of container ships[5]; services of arrival logistic center, transportation of containers by sea, transloading of the containers to another ship, services of departure logistic center, transportation of containers or products from the harbor to the users. The inbound and outbound transportation is usually road or rail, but it can be realized in the air (Fig. 1.).

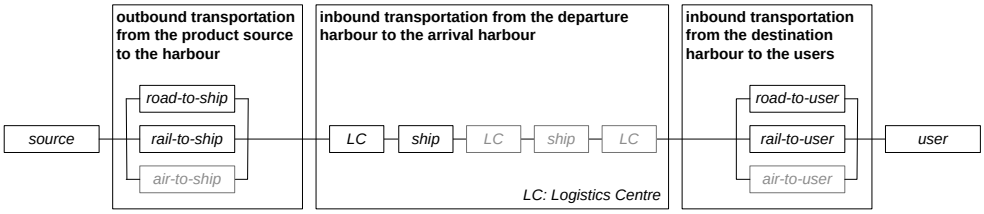

Figure 1. General model of intermodal transportation

[2] However Hungary is a small country, but it has a quite important position in the international intermodal and multimodal transportation. This is the most important reason, why the Hungarian transportation strategy includes some milestones for the development of intermodal and multimodal transportation.

[3] Today, there are almost 6 000 ships in the intermodal freight transport involved.

[4] Containers are generally 2.4 m wide and 2.4 m high. The common lengths are 6.1 m, 5.8 m, 12 m and 16 m. The identification of these containers is based on the ISO 6346 international standard.

[5] Harbours are usually big logistic centres, where the following typical services are available: logistic operation (warehousing, loading and unloading, building of loading units, packaging, disposition, collection and distribution), finishing, maintenance, custom, assurance, consultancy, banking, shipping document administration, etc.

4. Modeling of intermodal transportation

The intermodal supply is an integrated transportation chain. The model of this transportation chain includes the container ships to transport containers by sea, the road-to-ship or rail-to-ship transportation of containers from the producer to the harbors of container ships and the road-to-user or rail-to-user transportation to transport containers from the departure harbor to the users (Fig. 2).

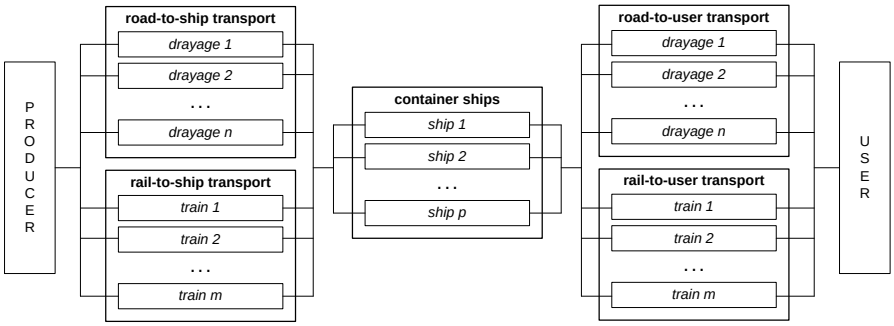

Figure 2. Model of intermodal supply from the producer to the user

The objective function of the optimization of this supply chain is the total transportation cost:

$$C^T = C^T_{RtoS} + C^T_{CS} + C^T_{RtoU} + C^S_O \Rightarrow min., \tag{1}$$

where C^T_{RtoS} is the cost of road-to-ship or rail-to-ship transportation, C^T_{CS} is the costs of container ships to be used to transport containers by sea, C^T_{RtoU} is the cost of road-to-user or rail-to-user transportation and C^S_O is the cost of outsourced services not included into the three transportation phases. The required services (customs formalities, insurance, consumer packaging, safe-keeping in the phase of warehousing, loading unit building or commissioning, etc.) can be summarized as follows:

$$S = S_{RtoS} + S_{CS} + S_{RtoU} + S_O\ , \tag{2}$$

where S_{RtoS} is included into the C^T_{RtoS}, S_{CS} is included into the C^T_{CS}, S_O is the outsourced services and S_{RtoU} is included into the C^T_{RtoU}. The products have to be transported to the end user before a predefined deadline, so the next constraint can be defined and has to be taken into consideration:

$$T^T = T^T_{RtoS} + T^T_{CS} + T^T_{RtoU} \leq T^{max}, \tag{3}$$

where T^T_{RtoS} is the total transportation time of road-to-ship or rail-to-ship transportation, T^T_{CS} is the total transportation time of container ships, T^T_{RtoU} is the total transportation time of road-to-user or rail-to-user transportation and T^{max} is the maximal transportation time. The scheduling of the three transportation phases is a very important aspect of this constraint, so the transportation time has to be included into the calculation of deadline:

$$D = D(T^T_{RtoS}, T^T_{CS}, T^T_{RtoU}) \leq T^{max}. \tag{4}$$

5. Harmony search based optimization of intermodal transportation problems

The harmony search algorithm is based on the performance process of musicians. Musicians try to find the best pitches to create a good harmony; engineers try to find the parameters to create a good system or process. In the optimization process of the above mentioned system, the musicians of the orchestra can be replaced with each decision variables of the intermodal supply. The optimization process consists of the following steps: define the problem and initialize the algorithm parameters; initialize the harmony memory; create a new harmony from the harmony memory; update the memory; repeat the steps until the termination criteria are satisfied[6].

The first step of the optimization process is the initialization of the problem, which is the objective function (1) with the constraints (2-4). The parameters of the algorithm must be specified: number of solution vectors in the harmony memory, harmony memory consideration rate, pitch adjustment rate and the termination criteria. The next step is the initialization of the harmony memory (Fig. 3). This step means the definition some possible solutions of the real problem. The third step is the calculation of new harmonies (new solutions of the real problem). This improvisation is based on the following formula:

$$p_i^* = \begin{cases} p_i^* \in (p_i^1, p_i^2, \dots, p_i^{HMS}) & with\ HMCR \\ p_i^* \in P_i & with\ (1 - HMCR), \end{cases} \quad (5)$$

where HMCR is the probability of choosing one parameter from the memory[7]. If the new harmony vector is better, then the worst one, then the worst one is deleted and the new one is included. This process has to be continued until the termination criteria.

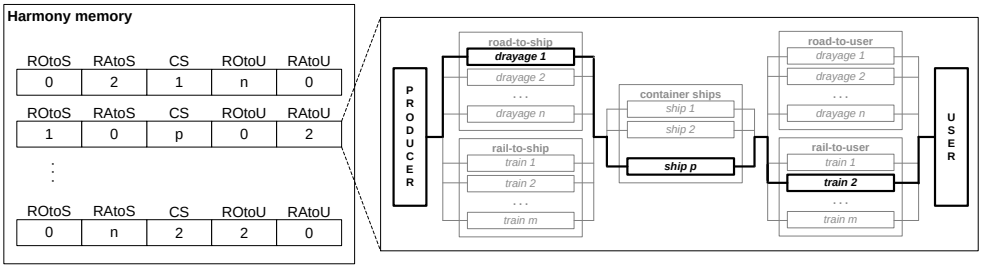

Figure 3. Harmony memory with chords (trials) representing the possible supply chain in the intermodal logistic system

The complexity is a quite important question of the problem. In the case of a huge number of products, and transport possibilities from the producer to the ships, and from the ships to the users this problem is a NP-hard problem so the application of this heuristic is justified.

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[6] The harmony search algorithm was published in 2001: Geem, Z. W., Kim J. H., Loganathan G. V.: A new heuristic optimization algorithm: harmony search. Simulation 76 (2). pp. 60-68.

[7] It is possible to perform a pitch adjustment with the parameters chosen from the harmony memory. Pitch adjustment means the increase or decrease of the chosen parameters with a predefined bandwidth. However the harmony search algorithm was developed to solve continuous optimization problems, but with discrete bandwidth it is possible to use the algorithm to solve discrete design problems.

6. Summary

The development and improvement of transportation infrastructure and network is a very important part of the today's economy. The transport industry represents almost 5% of GDP worldwide. It means that the optimal design and control of transportation systems is an economical question. Within the frame of this paper the author focuses on the design aspects of intermodal transportation. The first part of the work summarizes the logistics aspects of transportation improvement from the point of view globalized economy. The second part of the paper describes one possible model of intermodal transportation and shows a heuristic optimization method to find the optimal supply chain.

Acknowledgements

The research was supported by the TÁMOP 4.2.1.B-10/2/KONV-2010-0001 entitled "Increasing the quality of higher education through the development of research - development and innovation program at the University of Miskolc" supported by the European Union, co-financed by the European Social Fund.

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