FREIGHT AND WAREHOUSE EXCHANGES: MODERN LOGISTIC INFORMATION SYSTEMS

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Abstract The paper begins with a description about the services of electronic freight and warehouse exchanges currently available on the Internet, then, continues to point out their shortcomings. Based on this, it demonstrates the participants, the aims, the structure and the services of a logistically and economically ideal electronic freight and warehouse exchange system. Then it presents the e-commerce toolbar (catalogue, tenders, auctions), which gives the framework of choosing. It emphasises the application of a self-developed multi-criteria decision supporting algorithm (based on AHP – *Analytic Hierarchy Process* -) in the assessment of offers received for tender. The paper describes one optimum search problem emerging in electronic freight and warehouse exchanges, then presents, in details, the ant colony algorithm (BA_ACO) for its solution (to support the complex logistics processes). The demonstration of the modules and operational process of this system is done with the help of self-developed VBA-based (*Visual Basic Application*) algorithms.

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1. INTRODUCTION

With the help of the Internet, information can be sent to participants of business processes in the fraction of a second, which, by accelerating and optimizing these processes, facilitates an easy overview and comparison of supply and demand (Rayport & Jaworski, 2002); (Beynon-Davies, 2004).

For this reason, electronic marketplaces have emerged in numerous fields, such as *freight exchanges* in the field of carrier services. Freight exchanges create a meeting point for freighters and consigners. Consigners can advertise their freight tasks for shipment in the catalogue of the marketplace; similarly, freighters can make their bid for cargo holds. Moreover, the users of these exchanges can choose the most suitable offer by using different search algorithms (Kovács & Grzybowska, 2011). *Warehouse exchanges* sell free warehouse space/task either with a simple advertisement or by using an application which enables a search function.

The most complex form these days is when both freight and warehouse exchanges occupy a single advertising surface, where one can display their freight tasks, cargo holds (free freight capacities), storage tasks and warehouse space bids, as well as search among these offers in a catalogue format. Such exchange types enable to get hold of freight and warehouse capacities for goods relatively easily, and to find a transport or storage commission. Nevertheless, because underdeveloped transactional solutions set back the development of such exchange types. The overall structure of freight and warehouse exchanges is supplemented by showing other modules and services, too, in the forthcoming sections of the paper. These could be important and useful modules in the future.

2. MODERN FREIGHT AND WAREHOUSE EXCHANGE

2.1. The system model

The structure and modules of electronic freight and warehouse exchanges are shown by Figure 1 (Kovács, 2009). The developed freight and warehouse exchange offers the following main services: *e-commerce toolbar* (I+C: information and communication techniques); *multi-criteria decision supporting algorithms* (choose the best offer); *optimization algorithms* (optimize the logistics processes); other functions (e.g. statistics, blacklists, data maintenance, etc.). The electronic freight and warehouse exchange has three *participants*: consigners, logistics providers, and the system operator. The *aims* of the electronic freight and warehouse exchange: to advertise freight/storage capacities/tasks; to choose suitable offers based on e-commerce methods and complex optimum criteria (Winston, 2003); to support complex logistic processes (e.g. combined transport, city logistics, etc.).

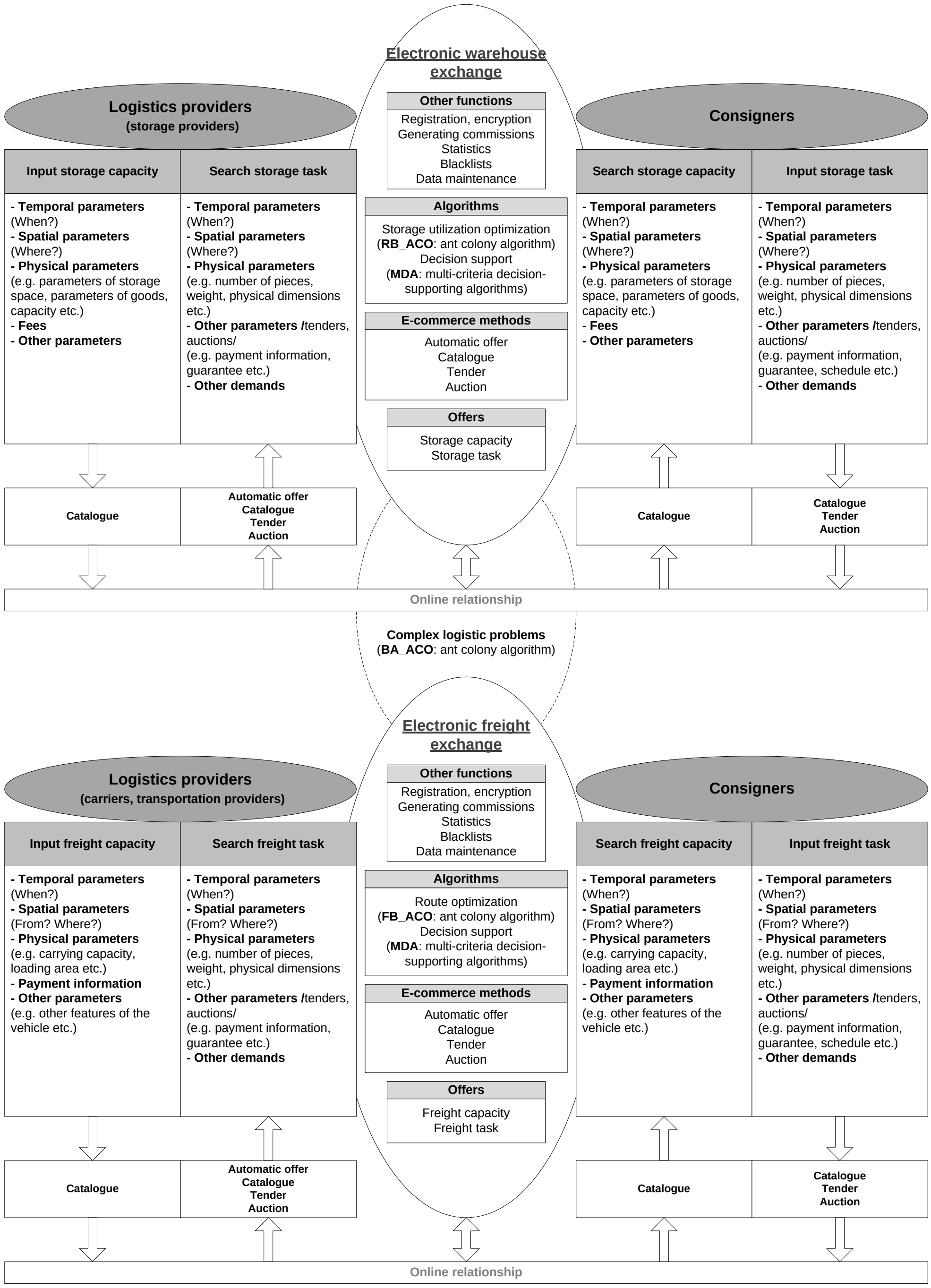

Fig. 1 The system model of the developed electronic freight and warehouse exchange (Kovács, 2009)

2.2. The e-commerce toolbar

When a new user who has not used the system before wants to register, their personal data and contact details must be entered. Also, we can specify here the filtering criteria, which are necessary for the automatic offer sending, and we can also add our personal negative experiences.

Consigners *specify the details* of their *freight/storage tasks* (e.g. temporal/spatial/physical parameters, etc.). Logistics providers can do a *search* based on the mentioned parameters. It is also possible to find backhaul and to look at the whole task offer here, too. Logistics providers can offer their *freight/storage capacities* by displaying all relevant information (e.g. temporal/spatial/physical parameters, etc.). Consigners can do a search based on the mentioned parameters. We can take a look at the whole cargo hold offer here, too.

After giving our personal data, the system allows us to enter filtering criteria which will help us to choose quickly from the latest offers (*automatic offer sending*, based on individual settings). Such criteria are: time, spatial or physical limitations, etc.

There is opportunity to have a freight/storage commission through *tender* or *auction* (Song & Regan, 2005); (Ihde, 2004). Experiences show that tenders for high- value and/or repetitive freight/storage tasks are worth advertising on the electronic freight and warehouse exchange. The organiser of the tender specifies the features of the freight/storage task in the subject of the tender, as well as tender parameters (e.g. payment, guarantee, schedule, etc.). Usually, the tender is won by the logistics provider who offers the lowest fare. Generally, it is worth considering other aspects, too, when evaluating tenders (see 3.1. subsection).

3. ALGORITHMS OF FREIGHT AND WAREHOUSE EXCHANGE

3.1. Multi-criteria decision supporting algorithm

One of the chief values of the developed electronic freight and warehouse system is the automatic application of multi-criteria evaluation methods that are well-known from books, but may not be used enough in practice. The developed mathematical method called multi-criteria decision-supporting algorithm, which help to evaluate tenders/auctions (Kovács, Bóna & Duma, 2008); (Kovács & Bóna, 2009). MDA based on the principle of the *AHP – Analytic Hierarchy Process* (Saaty, 1980); (Saaty, 1994). MDA enables to determine the weights of evaluation aspects under examination in mathematically correct way (Faddeeva, 1959). To this, one must set the importance ratio of the evaluation aspects based on discussions and agreement with, and validation by the consigner.

This is a vital step, as these settings create the internal, mathematical input, which generates the weights of evaluation aspects. In determining weights, consistency is underlined, because in case of inconsistency (there is contradiction in the importance of evaluation aspects in relation to each other) the evaluation system could give a false picture about the alternatives. Therefore, consistency, as well as the permitted level of inconsistency is controlled by an inner checking routine.

Offers received can be arranged in an order of *usefulness* (exactly calculated); based on the value they get from the pre-defined evaluation aspects, as well as the generated weights of the aspects (w_i, w_{ij}). Taking every main aspect (1…i…f) and sub aspect (1…j…a_i) step by step, we choose the value of the most favourable offer (T_{ij}^{max}, T_{ij}^{min}), and we compare all other offers (T_{ij}^{k}) to this (see equations (1) and (2)). The offers (1…k…o) get a *weighted performance value* (E_k, equation (3)) between 0…1, where the most favourable offer has the highest value. If an offer proves to be the most favourable in all aspects, it will get the performance value *1*. Performance values can be interpreted in a percentage context, meaning how *good* they are in relation to the *optimal offer*.

$$R_{ij}^{k} = \frac{T_{ij}^{k}}{T_{ij}^{max}}, \text{if } T_{ij}^{max} \text{ (the highest value) is the most favourable} \tag{1}$$

$$R_{ij}^{k} = \frac{T_{ij}^{min}}{T_{ij}^{k}}, \text{if } T_{ij}^{min} \text{ (the lowest value) is the most favourable} \tag{2}$$

$$\acute{E}_k = \sum_{i=1}^{f} \left\{ w_i \cdot \sum_{j=1}^{a_i} \left[w_{ij} \cdot R_{ij}^{k} \right] \right\} \Rightarrow \text{MAX!} \tag{3}$$

It happens fairly frequently that the difference between two or more solutions is very small. In such cases, a *sensitivity analysis* must be carried out, which examines what happens to the order of offers if weights are changed. First, it must be examined what happens to the best offer when changing the weights. We change the relative weight of one aspect between *0…1*; the weight ration of other aspects remains the same. *Four aspect types* can be determined: changing the weight does not affect the best alternative (*E-1*); the weight has a minimum limit below which the best offer changes (*E-2*); the weight has a maximum limit above which the best offer changes (*E-3*); the weight has both maximum and minimum limits, this could mean a change in the best offer (*E-4*). In addition, using the examined weights (*1…i…v*), the weights dependent on those changes (*v+1….j….f*) and the weighted performance values on the basis of sub aspects (c_i, c_j), we can calculate the *maximal sensitivity value* of alternative k.:

$$S_k(w) = \frac{\sqrt{\left[\sum_{i=1}^{v}\left\{c_i - \sum_{j=v+1}^{f}\left[\frac{w_j \cdot c_j}{\sum_{j=v+1}^{f}(w_j)}\right]\right\}\right]^2} \cdot \sqrt{\sum_{i=1}^{v}\{w_i^2\}}}{\sum_{i=1}^{v}\{w_i \cdot c_i\} + \sum_{j=v+1}^{f}\left\{[1-\sum_{i=1}^{v}(w_i)]\frac{w_j \cdot c_j}{\sum_{j=v+1}^{f}(w_j)}\right\}} \tag{4}$$

Table 1 MDA generated report in the course of a freight tender (example)

Main aspects			**Sub aspects**				**Offers and their values**					
Ser. No.	Name	Weight	Ser. No.	Name	Weight	Interpre-tation	1	2	3	4	5	Ideal
1	Fare (100 Euro)	.4082	1	Fare (100 Euro)	1	lower	421	525	590	586	448	421
2	Deadline (day)	.2041	1	Deadline (day)	1	lower	3	3	4	2	3	2
3	Proximity	.1361	1	Proximity	1	higher	0.3457	0.3457	0.1728	0.0494	0.0864	0.3457
4	Services	.1020	1	Services	1	higher	0.125	0.25	0,125	0.25	0.25	0,25
5	I+C connections	.0680	1	I+C connections	1	higher	0.1509	0.2264	0.4528	0.0566	0.1132	0.4528
6	References	.0816	1	General references	0.75	higher	0.2759	0.1379	0.1379	0.2759	0.1724	0.2759
			2	Trust	0.25	higher	0.1429	0.2857	0.2857	0.1429	0.1429	0.2857
1	Fare (100 Euro)	.4082					1	0.8015	0.7127	0.7186	0.9393	1
2	Deadline (day)	.2041					0.6667	0.6667	0.5	1	0.6667	1
3	Proximity	.1361					1	1	0.5	0.1429	0.25	1
4	Services	.1020					0.5	1	0.5	1	1	1
5	I+C connections	.0680					0.3333	0.5	1	0.125	0.25	1
6	References	.0816					0.875	0.625	0.625	0.875	0.5938	0.875
					Ser. No. of offers		**1**	**2**	**3**	**4**	**5**	
				Weighted performance value			**0.8254**	**0.7863**	**0.6310**	**0.6988**	**0.7210**	
		Final order of offers			**Ser. No. of offers**		**1**	**2**	**5**	**4**	**3**	
					Weighted performance value		**0.8254**	**0.7863**	**0.7210**	**0.6988**	**0.6310**	

Based on this, it is recommended to choose the final order after several changes in weights. MDA is an MS Excel and VBA-based (*Visual Basic Application*) system. By its decision making nature, it generates reports (Table 1, Table 2) that help making well-founded decisions. However, one should not forget that even the interpretation of results is not trivial in many cases. Consultation with an expert in this case is highly recommended, as he/she can explain the content behind the numbers.

Table 2 Critical aspects and their critical weights, along which the current results (offer No. 1 is the most favourable, see Table 1) are valid; maximal sensitivity S(w)

Sensitivity analysis					$S_1(w)$ %
Main aspects and their types		**Limits of weights**		**Nature of the change**	
		Lower limit	**Upper limit**		
Fare	E-2	0.2482	1.00	monotonically increasing	14.589
Deadline	E-3	0.00	0.4141	monotonically decreasing	4.931
Proximity	E-1	0.00	1,00	monotonically increasing	3.331
Services	E-3	0.00	0.1620	monotonically decreasing	4.480
I+C connections	E-3	0.00	0,2380	monotonically decreasing	4.351
References	E-1	0.00	1.00	monotonically increasing	0.534

3.2. Optimization algorithm

The basic function of electronic freight and warehouse exchanges is to establish connection between free freight and storage capacities and tasks. In the database of such online fairs there is high number of freight and storage capacity offers and tasks, which provides good *optimization opportunity for logistics providers* (Kovács, 2010). Over the current known applications, the electronic freight and warehouse exchanges are able to provide such logistic processes, in which the information and communication deficiencies between the participants cause the more significant problem. Based on this, the electronic freight and warehouse exchanges are able to organize *collecting and distributing routes* and *divide the certain transport/storage capacities between the logistic providers*. It is suitable for organize the transport and storage processes of the multimodal logistic centres (*combined transport* and *city logistics*). Therefore, these exchanges can provide the *green logistics* principles, mostly through the decreasing number of the trucks and the decreasing measure of the exhausted fumes. Based on all these this subsection describes one optimal search problem (from the three developed algorithms) emerging in electronic freight and warehouse exchanges, then presents, in details, an ant colony algorithm for its solution.

In case of freight and warehouse exchanges, we have to define a *complex objective function.* On a part of the total transport route, the freight tasks are transmitted together and then with the help of a combi terminal the freight tasks are transferred (multimodal transportation with rail/river, Fig. 2, *BA_ACO* algorithm). The objective functions (maximum benefit, *H,* see equation (5)): minimal transportation performance increase (Q^{CF}, ton*kilometre); maximal total mileage reduction (F^{CF}, kilometre); maximum use (K^{CF}) of the rail/river vehicle; optimum demand of the surplus logistic services (RI^{BF}).

$$H = RI^{BF} \cdot K^{CF} \cdot \frac{F^{CF}}{Q^{CF}} \Rightarrow MAX! \quad (5)$$

This problem can be solved by *ACO* (*ant colony optimization*), which is an optimizing algorithm developed by Marco Dorigo (Dorigo & Stützle, 2004) based on the modelling of the ants' social behaviour. In nature ants search for food by chance, then if they find some, on their way back to the ant-hill they mark the way with pheromone. Other ants – due to the pheromone sign – choose the marked way with higher probability instead of accidental wandering. Shorter ways may be completed quicker, thus on these ways more pheromone will be present than on longer ones. After a while the amount of pheromone drops (evaporation), by this preventing sticking to local optimum. In the electronic freight and warehouse exchange similar problem emerges as the ants' search for food: the target is the performance of freight tasks offering the higher profit (equation (5)). There are some researches in this topic (Bell & McMullen, 2004); (Tang, Zhang & Pan, 2010); (Bin, Zhong-Zhen & Baozhen, 2009).

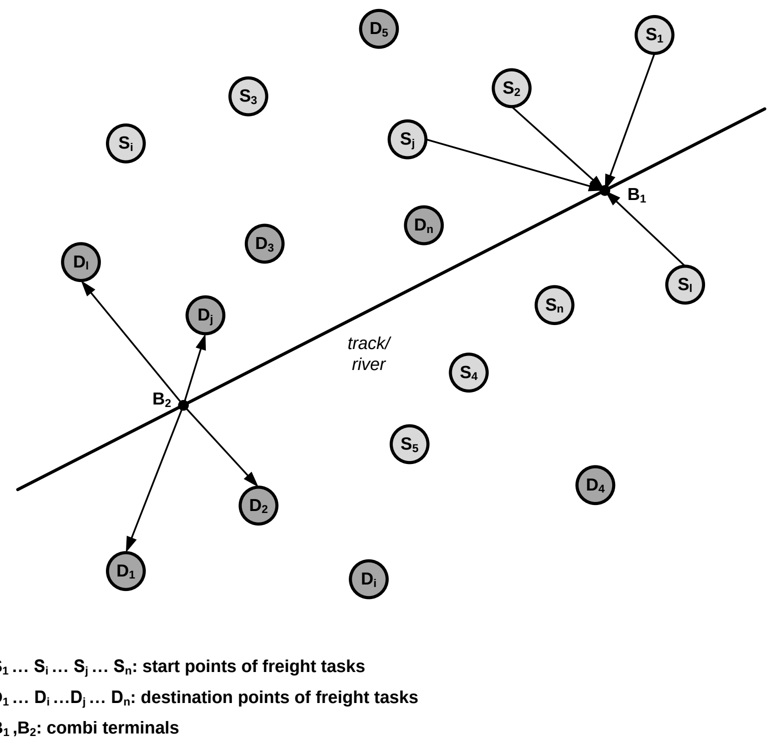

Fig. 2 Multimodal transport supported by freight and warehouse exchange (Kovács & Grzybowska, 2011)

The ant colony algorithm usable in electronic freight and warehouse exchanges (BA_ACO, tested in MS VBA) operates upon the following large-scale procedure:

1. Definition of input data:

   a. starting point of optimum search (e.g. *combi terminals*, etc.),
   b. narrowing down search space (*local search*): e.g. the selection of performable freight tasks depending on the distance compared to the combi terminals,
   c. collection of the main features of the combined/non combined transport (*mileage*, *transportation performance*),
   d. establishment of *pheromone vector* (the strength of the selection of freight tasks, initially contains only 1, φ_j, j=1…L, L: the number of optional freight tasks),
   e. settling of *profit vector* (how much profit the selection of freight tasks will bring from the aspect of the route/solution).
2. Calculation of task selection probability:
   a. the probability (p_j) that *j* freight task will be fulfill through combined transport (I_j: quantity of goods), (equation (6)):

$$p_j = \frac{\varphi_j^{\alpha} \cdot \left(\frac{1}{I_j}\right)^{\beta}}{\sum_{j=1}^{L}\left\{\varphi_j^{\alpha} \cdot \left(\frac{1}{I_j}\right)^{\beta}\right\}} \tag{6}$$

   b. α=2, β=1/3, parameter α control the influence of φ_j, parameter β control the influence of I_j; the value of α and β are based on lot of runs (pheromone is more important than the heuristic information /quantity/),
   c. a vector may be formed from the above-mentioned probabilities (equation (6), *probability vector*).
3. Establishment of solution possibilities:
   a. establishment of random numbers, then selection of freight tasks upon probability vector, until the realization of the limiting conditions (e.g. capacity of train),
   b. definition of the main features of the route (objective function parameters, equation (5)),
   c. execution of the above-mentioned tasks in accordance with the number of ant colonies (e.g. ten ants = ten versions).
4. Evaluation of the results of the iteration step:
   a. filling in the profit vector: freight tasks by freight tasks, choosing the highest profit in aspect of the total route/solution and set it in to the current freight task, then updating the maximum profit (H_{max}) reached in the iteration steps, if improvement was realized,
   b. *updating the pheromone vector* (equation (7)) (the $\mathcal{B}$=5/36 multiplier ensures balance between conservative and explorer search; H_{max} – the best profit during the iteration – results strong elitism; H_j: the best profit

if *j* freight task will be fulfilled with combined transport; ρ=0,1: rate of pheromone abrasion, pheromone amount is between 0.5 and 2):

$$\varphi_j = \left[\varphi_j + \mathcal{B} \cdot \varphi_j \cdot \frac{H_j}{H_{max}}\right] \cdot [1 - \rho] \tag{7}$$

5. Making new and new iteration steps (step 2., 3. and 4.) as long as further improvement cannot be reached (H_{max}), or after certain number of steps (Fig. 3).

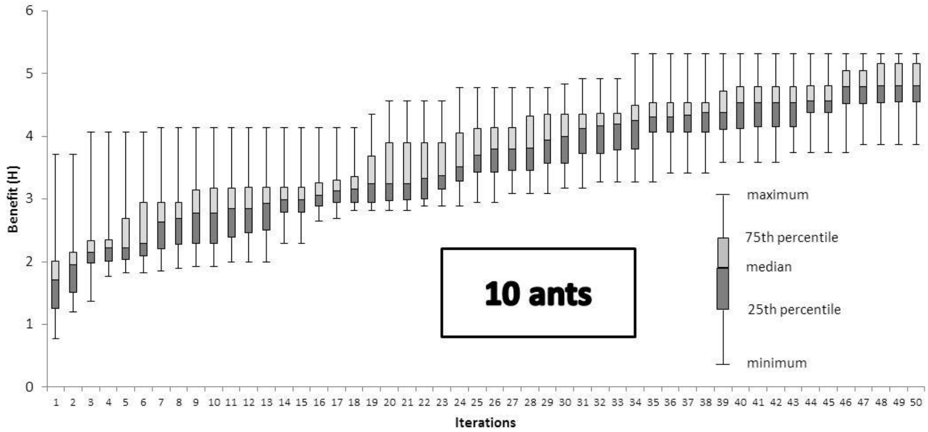

Fig. 3 Box plot chart (the changes of benefit (H); 10 ants, 40 runs, 50 iterations)

4. CONCLUSION

First of all, the main advantage of the developed system is, that a manifold optimum search tool is available in the electronic freight and warehouse exchanges. With the help of the presented methods (e.g. MDA, BA_ACO), by the filtering of local optimums, a solution can be found shortly, which to freight/storage capacities/tasks selects freight/storage capacities/tasks. There are a lots of optimization opportunities, from the decision making, to the route planning and utilization optimizing. In addition, complex e-commerce methods (e.g. tender, auction) help the selection.

The role of freight and warehouse exchanges in complex logistics problems (city logistics, combined transportation) may be viewed as the route planning systems of companies (e.g. wholesalers): the processes (e.g. tours, utilization) can be optimized by handling demands and capacities in one system.

Moreover, through the coordination they are able to establish collecting-distributing routes, to organize back haul, and through this to reduce the number of vehicles. In this way, support of complex logistics problems (city logistics, combined transportation) will be possible. In other words, freight and warehouse exchanges are one of the “simplest”, but still the most efficient way of optimizing complex logistics processes.

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BIOGRAPHICAL NOTES

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