Chapter

LOGISTICS PROCESSES SUPPORTED BY FREIGHT AND WAREHOUSE EXCHANGES

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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 optimising 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.

The Internet facilitates a forum for logistic service providers to advertise their service supply, such as transport and storage on the worldwide web; whereas customers can choose the offer, which best suits their needs. Nowadays the most widespread form of freight exchanges on the Internet can provide only a single advertising surface for both the consigner and the freighter. More sophisticated freight exchanges can ensure the advertising of freight and cargo hold offers, as well as the filtering and evaluation of these by putting in a separate application. However, even these freight exchanges focus only on displaying and searching for offers in a catalogue format, and they do not ensure other forms of transactional solutions (e.g. how to advertise or choose offers).

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Warehouse exchanges - similarly to freight 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 chapter. These could be important and useful modules in the future.

2. THE SYSTEM MODEL OF A MODERN ELECTRONIC FREIGHT AND WAREHOUSE EXCHANGE

The structure and modules of the electronic freight and warehouse exchange is shown by Fig.1 (Kovács, 2009). When describing freight and warehouse exchanges, it is practical to handle the freight and the warehouse exchange as two separate modules, which display for the end-user on a single surface.

The developed freight and warehouse exchange offers the following main services:

1. e-commerce toolbar (I+C; information and communication techniques):
    a. advertising and searching in a simple catalogue (freight/storage tasks/capacities),
    b. automatic offer sending (based on individual settings),
    c. tenders/auctions (just for freight/warehouse tasks), (Ihde, 2004),
2. multi-criteria decision supporting algorithms (choose the best offer),
3. optimization algorithms (optimize the logistics processes),
4. 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:

1. to advertise freight/storage capacities/tasks,
2. to choose suitable offers based on e-commerce methods and complex optimum criteria (Winston, 2003),
3. to support complex logistics processes (e.g. combined transport, city logistics, etc.).

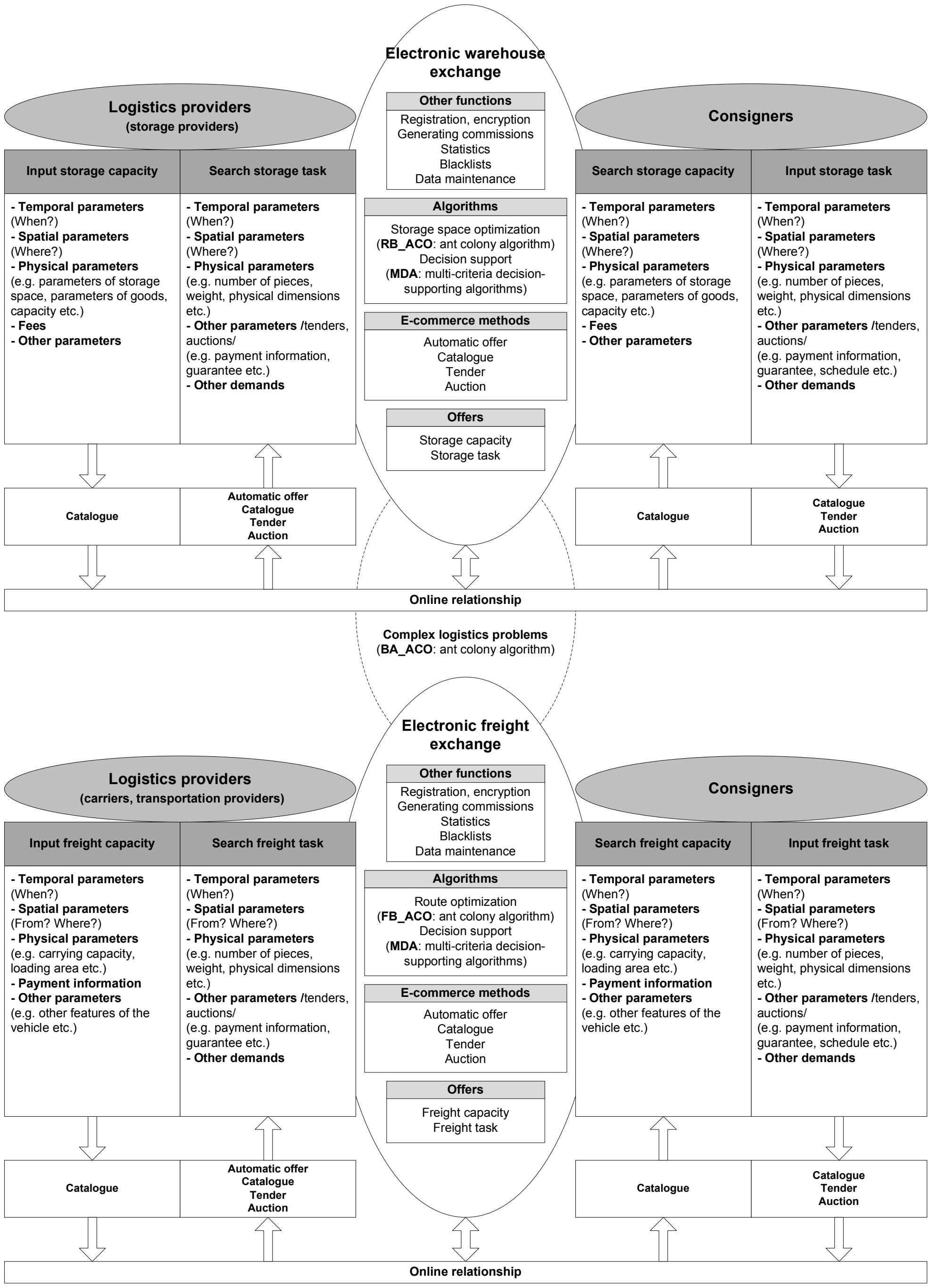

Fig. 1. The system model of the developed electronic freight and warehouse exchange

3. THE E-COMMERCE TOOLBAR

When a new customer 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.

Enter data and search offers with a catalogue:

1. Consigners specify the details of their freight/storage tasks (e.g. temporal/spatial/physical parameters, etc.),
2. Logistics providers can do a search based on temporal/spatial/physical parameters. It is also possible to find backhaul and to look at the whole task offer here, too,
3. Logistics providers can offer their own freight/storage capacities by displaying all relevant information (e.g. temporal/spatial/physical parameters, etc.),
4. Consigners can do a search based on temporal/spatial/physical 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.). Such criteria are: time, spatial or physical limitations, etc.

There is opportunity to have a freight/storage commission through tender (Fig. 2, auctions like this), (Song, & Regan, 2005). 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 4. subsection).

4. MULTI-CRITERIA DECISION SUPPORTING ALGORITHMS

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, (*MDA*, Fig. 3) 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.

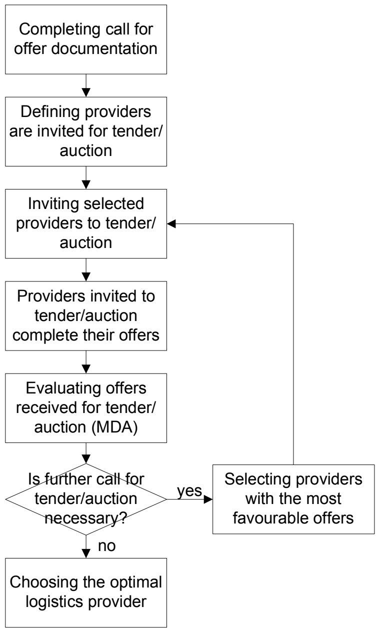

Fig. 2. The process of tenders/auctions in electronic freight and warehouse exchanges

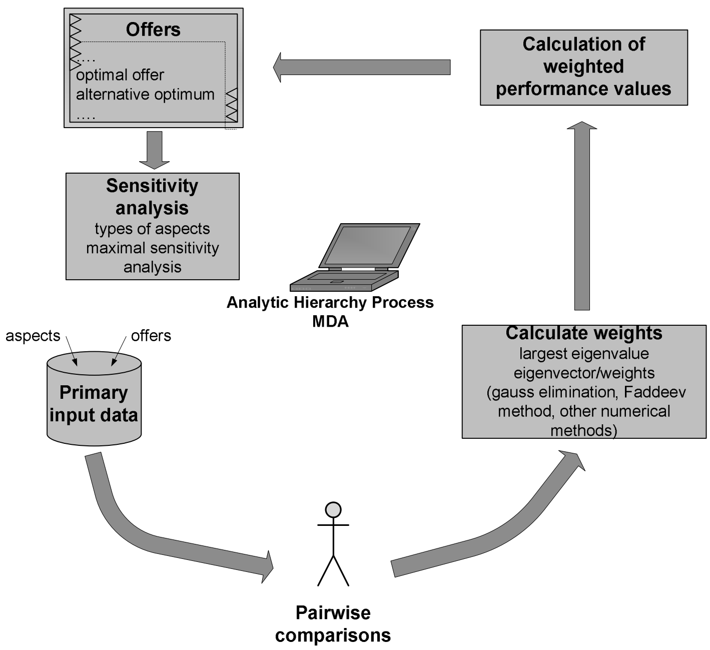

Fig. 3. The process of the multi-criteria decision-supporting algorithm (MDA)

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".

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

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

$$E_k = \sum_{i=1}^{f} w_i \sum_{j=1}^{a_i} w_{ij} R_{ij}^{k} \quad (3)$$

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. One must examine 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:

1. changing the weight does not affect the best alternative (E-1),
2. the weight has a minimum limit, below which the best offer changes (E-2),
3. the weight has a maximum limit, above which the best offer changes (E-3),
4. the weight has both maximum and minimum limits, this could mean a change in the best offer (E-4).

In addition, based on the mathematical maximal sensitivity analysis (equation (4)), we can also calculate a percentage value, which features the rate of sensitivity:

$$S(w) = \frac{\sqrt{\sum_{i=1}^{f}\left(\frac{\partial}{\partial w_i} E_k(w)\right)^2} \sqrt{\sum_{i=1}^{f} w_i^2}}{E_k(w)} \quad (4)$$

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 (Tab.1, Tab. 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.

Tab. 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**	**Interpretation**	**1**	**2**	**3**	**4**	**5**	**Ideal**
1	Fare (100 Euro)	0,4082	1	Fare (100 Euro)	1	lower	421	525	590	586	448	421
2	Deadline (day)	0,2041	1	Deadline (day)	1	lower	3	3	4	2	3	2
3	Proximity	0,1361	1	Proximity	1	higher	0,3457	0,3457	0,1728	0,0494	0,0864	0,3457
4	Services	0,1020	1	Services	1	higher	0,125	0,25	0,125	0,25	0,25	0,25
5	I+C connections	0,0680	1	I+C connections	1	higher	0,1509	0,2264	0,4528	0,0566	0,1132	0,4528
6	References	0,0816	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)	0,4082					1	0,8015	0,7127	0,7186	0,9393	1
2	Deadline (day)	0,2041					0,6667	0,6667	0,5	1	0,6667	1
3	Proximity	0,1361					1	1	0,5	0,1429	0,25	1
4	Services	0,1020					0,5	1	0,5	1	1	1
5	I+C connections	0,0680					0,3333	0,5	1	0,125	0,25	1
6	References	0,0816					0,875	0,625	0,625	0,875	0,5938	0,875
					Ser. No. of offers		1	2	3	4	5	
					Weighted performace 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 performace value	0,8254	0,7863	0,7210	0,6988	0,6310

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

Sensitvity analysis					S(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%

5. OPTIMIZATION ALGORITHMS

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 providers (Kovács, 2010). Based on all these this subsection describes one search problem (there are developed three algorithms) emerging in electronic freight and warehouse exchanges, then presents, in details, an ant colony algorithm for its solution.

In the freight exchange the optimum search task may be formulated on the basis of the following objective function: those having free freight capacity wish to establish routes providing optimal profit from the freight tasks appearing in the freight exchange. Many freight tasks may be included into the route, but a new freight task may be commenced only after the completion of the previous one. The objective function is to reach the maximum profit (*FB_ACO* algorithm).

In the warehouse exchange those having free storage capacity wish to choose several from the available storage tasks by setting the goal of ideal exploitation of capacity (*RB_ACO* algorithm).

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. 4, *BA_ACO* algorithm). The objective functions (maximum benefit, *H*, see equation (5)):

1. maximum use (K^{CF}) of the rail/river vehicle,
2. maximal total mileage reduction (F^{CF}, kilometre),
3. minimal transportation performance increase (Q^{CF}, ton*kilometre).

$$H = K^{CF}\frac{F^{CF}}{Q^{CF}} = MAX! \tag{5}$$

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).

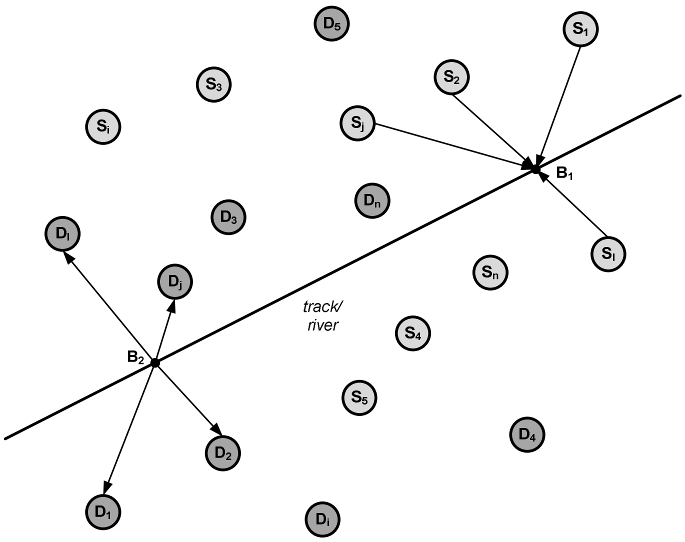

Fig. 4. Multimodal transport supported by freight and warehouse exchange

The ant colony algorithm usable in electronic freight and warehouse exchanges (BA_ACO) operates upon the following large-scale procedure (Fig. 5).

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 fulfil through combined transport (I_j: quantity of goods), (equation (6)):

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

   b. α=2, β=1/3, parameter α control the influence of φ_j, parameter β control the influence of I_j,
   c. the value of α and β are based on lot of runs (pheromone is more important than the heuristic information /quantity/),
   d. a vector may be formed from the above-mentioned probabilities, equation (6) (probability matrix).
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,
   b. updating the maximum profit (H_{max}) reached in the iteration steps, if improvement was realized,
   c. updating the pheromone vector (equation (7)) (the 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):

$$\varphi_j = \varphi_j + \frac{5}{36}\varphi_j\frac{H_j}{H_{Max}} \quad (7)$$

   d. pheromone abrasion (rate of pheromone abrasion ρ=0,1, equation (8), pheromone amount is between 0,5 and 2):

$$\varphi_{r,s} = \varphi_{r,s} * (1-\rho) \quad (8)$$

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.

The algorithms were coded and tested in MS Visual Basic language (Fig. 5 and Fig. 6), as well as formulas and their characteristics. In the course of checkout there are executed a lot of runs (Fig. 6).

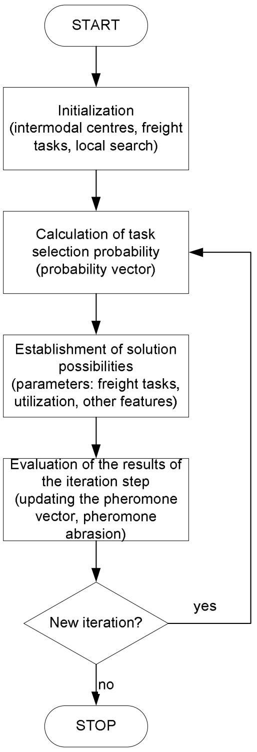

Fig. 5. The process of the BA_ACO algorithm (support of combined transport)

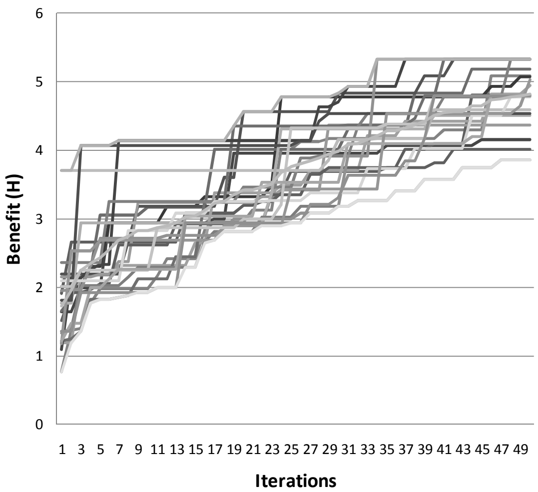

Fig. 6. The changes of benefit (H) in the course of BA_ACO runs (40 runs, 50 iterations)

6. CITY LOGISTICS SYSTEMS SUPPORTED BY ELECTRONIC FREIGHT AND WAREHOUSE EXCHANGES

The basic task of electronic freight and warehouse exchanges is to match capacity demands with capacity supplies. In the simplest case a consigner mandates the freighter to transfer a certain amount of goods (which causes a certain vehicle utilization) from one place to another. At this time, two significant problems emerge: on one hand, the utilization of vehicles may be low, and on the other hand, the possibility of backhaul is not certain. At this point the organizational function of electronic freight and warehouse exchanges becomes significant, because there is possibility to find the freight task resulting in the optimal capacity utilization, or even the simultaneous transfer of the goods of more than one freighters (if the characteristics of the goods make this possible), and the possibility of organizing backhaul is given, too. These characteristics make freight and warehouse exchanges suitable for the development of efficiency of urban transport of goods, because with their help trade directed to the city may be performed with lower number of vehicles, by this causing less environmental harm.

The efficiency of freight exchanges may be understood easily through a factual example. An imaginary region may be seen in Fig. 7, of the four of its settlements one may be considered centre (no. 1), the others are middle-sized (no. 2 and no. 3) and small settlements (no. 4). The settlements are divided into further districts, in order to provide for the concentration of trade directed to one district.

Demands and capacities related to the cities may be matched upon their characteristic features (start point and destination, goods specifications, time of delivery), and similarly to the presently known and used route planning systems „tours" may be modelled. Fig. 7 provides an example, where two routes were established (on the „map" indicated with dashed and double-dotted lines).

In the case of the route indicated with dashed line possible methods of trade/route between a medium sized city (no. 3) and the centre are described, into this tour the fulfilment of the demands of a village on the route (no. 4) was included, as well. At the end of the tour the possibility of backhaul is given, therefore the utilization of the vehicle is further increased. As it may be seen, the organization of such route – into which six different addresses and three different settlements are included – would be more difficult in the ordinary way and certainly would generate higher vehicle numbers. At the organization of routes in addition to the already considered aspects others, such as loading order shall be taken into account.

In the case of the tour indicated with the double-dotted line the indicated demands of all larger settlements in the district are fulfilled. The vehicle supplies the centre from city no. 2, and from here transports further goods to city no. 3. Therefore, due to the possibilities provided by freight exchanges (especially the simultaneous overview of a large number of demands) the supply of entire districts may be optimized (fewer vehicles arrive into the city with better utilization values; the order of visits may be optimized).

A characteristic and also a slight disadvantage of the solution detailed in previous section is that it is suitable for the organization of transfer of typically small quantity of goods, i.e. not of full load, because the procedure of matching more demands to one capacity makes sense only in this case. In reality many consignments filling the entire vehicle are transferred between cities and surrounding settlements. The known possible solution for such problem is the establishment of a transfer terminal (combi terminal) in the outskirts of the city where from larger vehicles arriving to the outskirts of the city the goods are transferred to lower numbers of vehicles of larger capacity, which occasionally are more environment friendly (BA_ACO, subsection 5.).

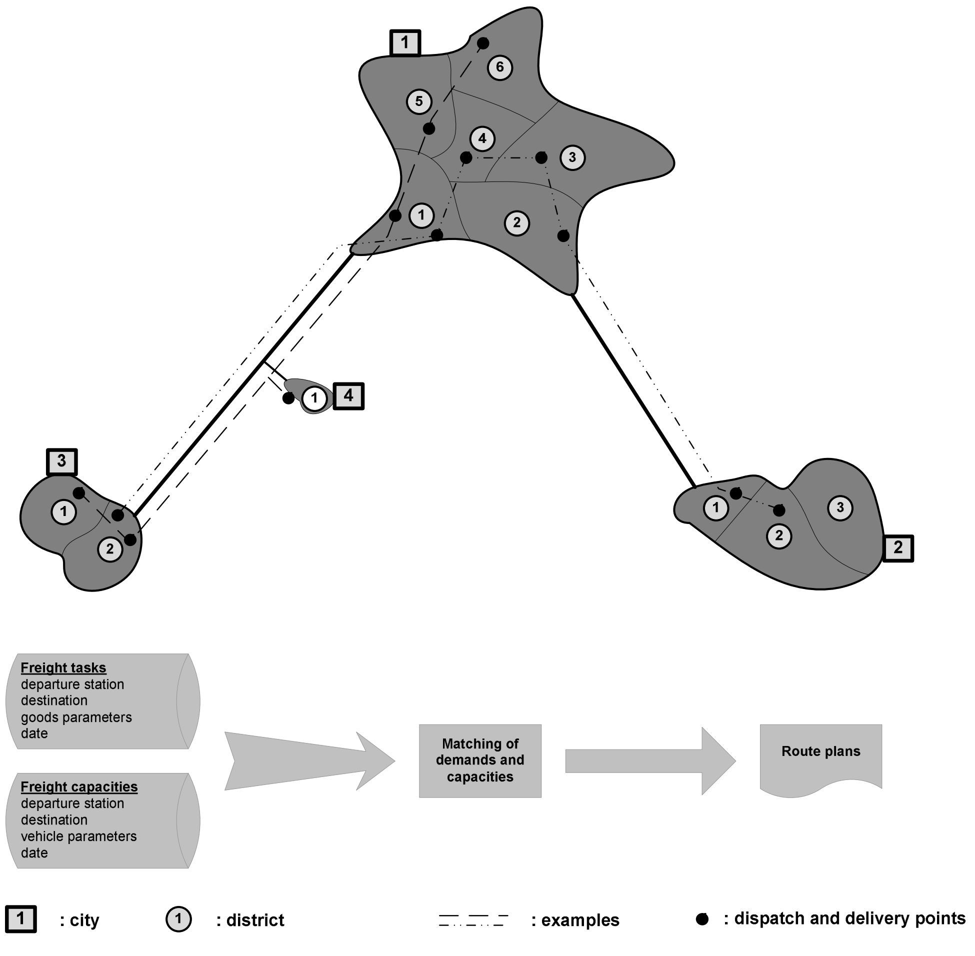

Fig. 7. Freight and warehouse exchanges for solving city logistics problems

Electronic warehouse exchanges provide supplementary solution to the above-mentioned model, at which storage place may be booked – for temporary storage – for transferable goods. Considering Fig. 7 let us assume that at the borders of the centre one or more transfer terminals are established (or even one such establishment is placed at each main road), and the capacities of these may be booked. Freighters, therefore, may optimize their out of centre trade with the freight exchange, while when they arrive to the borders of the city they may place their goods to the storage place booked at the warehouse exchange. The goods will be further transferred to the districts of the city with larger capacity vehicles, which vehicles may be chosen at the freight exchange, as well. In other words the routes are departed to the districts of the city in daily fixed times may be booked through the freight exchange. Warehouse exchange, therefore, has a supplementary role: it provides the possibility of choosing storage place established for the reduction of vehicle traffic arriving to the city to various directions (Kovács, 2010).

7. CONCLUSION

First of all, the main adventage 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 lot of optimization opportunities, from the decision making, to the route planning and utilization optimising. 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 is one of the “simplest”, but still the most efficient way of optimizing complex logistics processes.

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