THE ASPECTS OF ECONOMIC AND ENVIROMENTAL OPTIMIZATION IN AN E-MARKETPLACE INTEGRATED VIRTUAL TRANSPORT ENTERPRISE

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Abstract: The paper introduces the concept of the e-marketplace integrated virtual transport enterprise, defining it as an extension of the multi-purpose electronic transportation marketplace. The theoretical foundation of this approach is laid down in the first three chapters, while the fourth chapter presents the possibilities of optimization in such organizations. A unique possibility could be the implementation of multi-leveled optimization, as the organizational structure of the proposed enterprise model is naturally compatible with that paradigm. Besides these aspects of the proposed model, the possibilities of energy rationalization inside the virtual enterprise are also promising.

Keywords: virtual enterprise, e-marketplace, optimization, energy rationalization

Introduction

One of the aims of the current paper is to present the conceptual model of the E-marketplace integrated virtual transport enterprises. Such organizations can be viewed as natural advancements of the traditional transportation electronic marketplaces, which are in use inside the industry since several decades. The paper puts significant emphasis on the precise definition of the proposed organizational concept, which is based on the adequate formulation of the integration process among the components of the virtual enterprise.
After this, the possible approaches of optimization are going to be described, together with the detailed description of an integrated optimization method, which tries to unify the benefits of both the centralized and decentralized approaches. This is in line with the basic concept of virtual organizations, which assumes the existence of interorganizational coordination among the members of the organization, without the utilization of a central controlling entity.
The main advantage of the proposed solution is that it not only increases the cost and logistical efficiency of the virtual organization, but through the realization of better fuel-management at the individual SMEs, it also helps to reduce the energy dependency and environmental load inside the covered transportation system.

1. Utilization of electronic marketplaces inside the freight-transport industry

The widespread adoption of electronic marketplaces mainly occurred during the last two decades, in parallel with the large scale spreading of the Internet (it has to be noted, that the B2B type electronic commerce has already been active on closed networks before). The chief aim of these marketplaces is to realize the distribution of the manufacturers production capacities among the buyers, according to the laws of the free market (hence came the designation). Their implication provides numerous benefits and some drawbacks as well, however, the widely accepted view is that they are mainly beneficial for the small-and medium sized enterprises. In the followings, the main characteristics of these E-marketplaces are going to be presented, together with some practical examples from the transportation industry.

1.1 General introduction of transportation electronic marketplaces

Electronic marketplaces can be viewed as scenes of the e-commerce realized between the vendors and the customers [2.]. The literature makes a distinction between B2C (Business to Customer) and B2B (Business-to-Business) E-marketplaces. The individual customer is usually familiar with the first of the two types (through the use of electronic stores like Amazon.com, on-line auction websites like E-bay, electronic stores specialized for the sale of specific products, etc.), however the paper’s topic is in connection with the second type.
From the aspect of the maintainers of B2B E-marketplaces, we can distinguish between different models: the buyer-oriented model, where the maintainer of the E-marketplace is an individual company or consortium with a significant customer potential, who maintains the marketplace for it’s possible suppliers; the seller-oriented model, which is maintained in the previous way but for the potential customers of the company or consortium; the mediator model, where the marketplace is maintained by an independent 3rd party [2.]. The E-marketplaces created for the sale of transportation services can be categorized into the 1st and 3rd groups. Based on their working mechanisms, we can further categorize the latter institutions into: [3.]

- clearing houses,
- freight exchanges,
- auction houses.

In a clearing house, the customers (shippers) post their demands, while the vendors (carriers) post their free capacities. If an actor finds a suitable solution on the other side, then the negotiation could start between the two parties. This process is based on a database that consists either the loads posted by the shippers, or the transport capacities posted by the carriers [3.].
Freight exchanges are in many ways similar to clearing houses, however in this case, the negotiation usually takes place on the E-marketplace. Therefore, such institutions usually provide a range of additional services that can help in the efficient handling of the negotiation process. The latter usually involves the use of specialized agents on both sides and these can also be software tools with artificial intelligence, depending on the level of automation which is implemented on the marketplace [3.].
For the realization of long-term transportation contracts, the most widely used method is that of the use of combinatorial auctions. In such negotiations, the vendors not only offer a single item, but a set of different items for the potential customers. Then the customers can make their bids for the optional subsets of the initial set, which has the consequence that a combinatorial auction can have multiple winners. However, it is a requirement that all of the items have to be sold during the auction, moreover that a single item can only fall into the possession of one bidder.
On those auction houses which serve for the realization of long-term transportation contracts, the auction proceeds in the opposite way: a customer (shipper) offers the routes on which she requires transportation services. Then the vendors (carriers) post their bids for the routes

which they would like to serve. In this case, the bids consist the prizes the vendors would like to receive in return of the provided service (e.g. the transportation of the customer's goods), therefore it is natural that the combination with the lowest total price will be the winner one (at least in the majority of the cases).

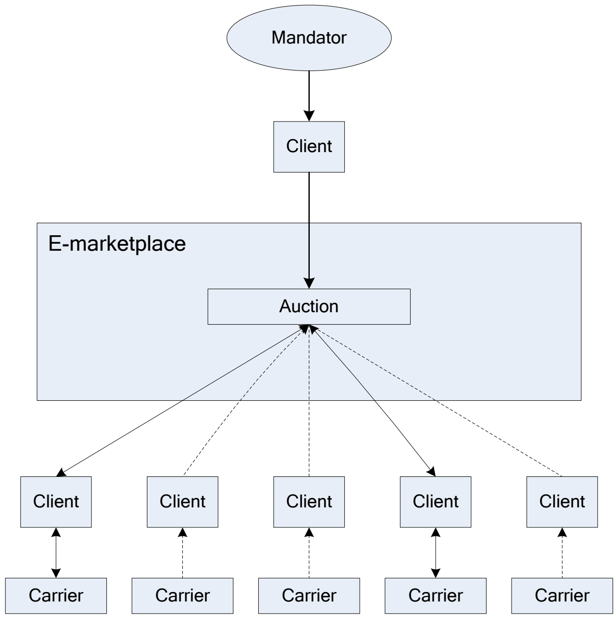

Figure 1. General implementation of the auction-based e-commerce inside the freight transport industry

The importance of the auction's combinatorial nature is that from the aspect of a given carrier, the offered routes can frequently relate to each other [4.]. A typical example can be the case, when a carrier can insert several of the routes into his already existing network in such a way that not only generates more profit, but also decreases the number of empty vehicle trips in the network. A more special variant of the previous case is that when the chosen routes can be inserted into a round trip. Therefore in such cases, the carrier can not only increase it's income, but can also decrease it's specific transportation costs (due to the lower number of empty vehicle trips inside it's network). It follows that the carriers can utilize a lower pricing level, if they can chose out the most appropriate combination of the set of the routes which is posted by the shipper. Thus it is evident that the use of the previously described auction mechanisms can be highly beneficial for both sides.

In practice, combinatorial auctions are in use for almost two decades inside the freight transport industry. However it has to be noted that the method is primarily used in conjunction with the realization of long-term transportation contracts, as the short-term assignments are usually contain only a single route, therefore the use of combinatorial auctions would not make any difference in the latter case.

1.2 Examples inside the industry

One of the first users of combinatorial auctions in the freight transport industry was Sears Logistics Services (SLS), an American company that was able to save more than 84 million dollars in the early 90's by applying the method for choosing it's logistical service providers

on it’s network of 854 routes [5.]. This example was later followed by other companies, like the also American Home Depot, the world’s largest home improvement retailer which used the method with prominent success at the beginning of the new millennium [5.].
In the above examples, the marketplace was operated by a single customer, therefore these can be sorted without question into the first group of B2B E-marketplaces, which represents the buyer-oriented model. Later, the independently operated E-marketplaces also came into existence, on which numerous customers (shippers) and vendors (carriers) are present at the same time. Such marketplaces are operated by entities like Freightmatrix, Freight-Traders, Transcore, Transplace and numerous other enterprises which are not listed here [3.]. In many cases, these marketplaces provide other value added services as well, for example the use of optimization software for the carriers, or the ability of cargo tracking and the use of decision support tools for the shippers. Moreover, in the previous examples the marketplace usually supports the realization of both the short-term and long-term contracts [3.]. Besides these, there are such virtual institutions which expressly concentrate on the realization of short-term assignments. A good example for the latter is the Turkish ESO logistics center, which was founded in 2003 near the city of Eskisşehir [6.]. This is a physically existing logistical center, one which maintains it’s own electronic marketplace for the purpose of supporting the realization of the freight assignments that are implemented with the help of its services. The ESO also uses an auction mechanism, but as the assignments in this case are single items, therefore the auction is not a combinatorial one [6.].
All of the above listed organizations are almost exclusively concentrate on road-based transportation, but examples can be found for the uses of E-marketplaces in other branches of transportation as well. Such examples are the GoCargo.com in maritime transport, or the Global freight exchange (lately Descartes GF-X Exchange) in air freight transport [3.]. The latter industry is also characterized by the formation of the so-called Cargo Community Systems (CCS), which have the aim of supporting the small-and medium sized freight forwarders with different IT solutions (E-marketplace, EDI, etc.).

2. Introduction of the E-marketplace integrated virtual enterprise

The virtual enterprises receive an ever increasing attention in the modern logistics research. The primary reason behind this tendency is that the dominant part of today's logistics systems operate in a network-like manner, which is usually based on some form of cooperation among self-autonomous organizations. The natural consequence of this practice is that the more highly organized logistics networks show similarities in their operation to the virtual enterprises. However, a constantly recurring problem of the field is that a universally accepted definition of the virtual enterprise is still missing in the literature, while a significant number of individual approaches to the problem can be found. From a certain point of view, this can be considered natural, as all existing organizations have their unique characteristics, however, from the aspect of the ongoing research activities, it would be beneficial to lay down the definitive characteristics of virtual enterprises.
The next chapter of the paper tries to provide the basis for the previous goal, doing so by starting out from the most general definition of virtual enterprises. Later, it introduces the concept of the E-marketplace integrated virtual enterprise, which could be one answer for the problem of how to implement a virtual organization (it has to be mentioned that, according to the knowledge of the author, although the term "E-marketplace integrated virtual enterprise" hasn't been introduced so far, several organizations most likely operate similarly to the proposed model).

2.1 General definition of virtual enterprises

According to the most accepted general definition, the virtual enterprise can be considered as a group of geographically dispersed, self-autonomous organizations and enterprises, which temporarily operate in a cooperative manner in order to achieve a mutual goal or a set of goals, while the individual organizations keep their complete autonomy. Of course, this definition only gives a conceptual frame, as in practice, several different type of organizations could fulfill the previous requirement (for example business clusters, supplier networks, etc.). However, according to the views of the author, a main aspect at the categorization of the different network-like organizations could be the fulfillment of the criteria, that the individual enterprises inside the organization must have their own autonomy preserved. Therefore, the cooperation among the individual units has to be realized through the coordination of the resources and information, rather than the use of a single controlling entity.

The previous requirement could be fulfilled through the implementation of some form of a distributed intelligence based network, where the role of the third party is "just" to maintain the information system, which connects the members of the virtual organization. The coordination could be realized through the use of this common infrastructure, and through the implementation of a commonly accepted set of rules, which partially govern the behavior of the individual members inside the organization. As can be seen, the E-marketplace integrated virtual enterprises (which can also be originated from the model of the electronic store) suit well into the previous concept.

2.2 The concept of the E-marketplace integrated virtual enterprise

The essence of the E-marketplace integrated virtual enterprise, as the definition clearly shows, is that the distribution of the organization's resources takes place on an electronic marketplace. In the simplest case, this marketplace could be a single web page, which creates the possibility for the small-and medium sized enterprises to find their optimal partners (usually suppliers or service providers) through this medium.

Of course, in this form, the system would not be significantly more than a closed electronic marketplace maintained for a certain group of enterprises. However, it was clearly demonstrated in the second chapter that such systems can also effectively support the accomplishment of more complex interorganizational tasks, mainly by providing different complementary services. In the field of logistics, such services can be route optimization, cargo tracking and tracing, allocation of storage capacities, implementation of paperless data communication between the parties (most often through the use of EDI), etc. With the integration of such services, the E-marketplace could truly become capable of the organization of complex interorganizational operations, especially if the negotiation processes are highly automated (generally through the use of intelligent agents).

Besides the previous possibilities, commonly accepted bidding-and transaction rules could be introduced on the internal marketplace, which alone could realize a form of coordination in an implicit manner. However, this solution also fulfilles also leaves the decision autonomy of the individual parties intact, and the internal marketplace can be viewed as a medium that creates the cohesion among the participating SMEs. As can be seen, in such a model every decision is made in the scope of the individual members, while from an outside point of view, the whole system truly resembles to a single organization. In other words, such systems can be categorized into the family of holonic organizations.

The next chapter will demonstrate a system operating in this manner for the freight transport industry.

3. The model of the E-marketplace integrated virtual transport enterprise

The E-marketplace integrated virtual transport enterprise can be defined as a special case of the previously outlined model. The main characteristic of such an organization is that the system mainly concentrates on the optimal distribution of transport capacities (complemented by other auxiliary services). As it could be seen in the second chapter, the electronic marketplaces themselves have a reasonable history inside the industry, however, alone they can not be considered virtual enterprises, as they lack a commonly accepted framework which could serve the basis of higher level cooperation. Therefore, in order to create a true virtual transport enterprise, first this framework has to be outlined and implemented, in line with the willingness of the participants. The framework, in its most basic form, should contain the following elements:

- qualification of the transport companies (carriers) according to their real performance, moreover the utilization of these results at the determination of the group of the participating carriers,
- utilization of a commonly accepted auction mechanism (ideally a closed, single round combinatorial auction),
- use of a single and common optimization tool, provided by the third party that maintains the marketplace, at the formulation of all the bids,
- use of a common client program for accessing the system, also provided by the third party, which, among other services, realizes complete EDI connection among the members of the virtual enterprise.

The above outlined framework formulates the minimal requirements, but naturally, other rules and coordinative tools could be integrated into the system as well. However, all advancements over the basic system should be introduced in a joint manner, in order to provide equal conditions to all members. The basic functionality of the outlined system is represented by the figure 2., where the dotted line represents the calling for bids, and the continuous line represents the bidding process.

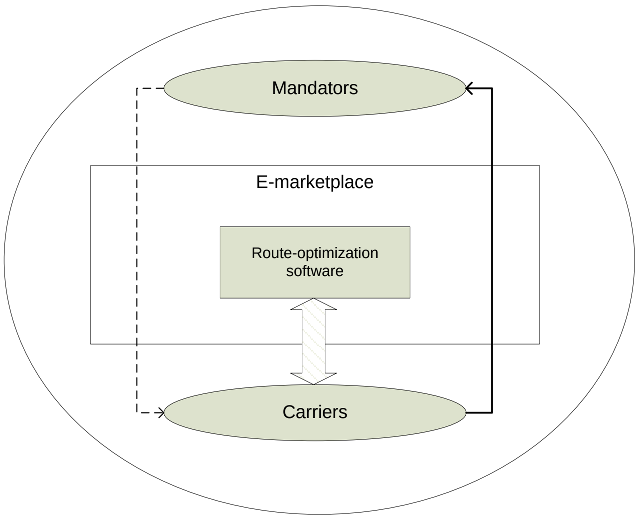

Figure 2. Working concept of the e-marketplace integrated virtual transport enterprise

One reasonable advantage of the presented model is that the real system can be introduced through a sequence of consecutive steps, where the individual members could jointly determine the level of integration inside the organization, taking into account the previous experiences. This is important, because in many cases, the greatest problem arises at the practical implementation of the given virtual enterprise model, because the future members of the organization are often unable to see the concrete benefits of their participation, while they might also have concerns about the effective functioning of the system. However, the proposed flexible architecture allows the gradual implementation of the system, starting from the introduction of a freely accessible and simple electronic marketplace, which doesn't require the introduction of any restriction among the members.

Another advantage of the model is that it realizes a two-level optimization approach: on the first level, the carriers optimize their routes during the bidding process, while on the second level, the mandators choose the optimal offer from the incoming bids. This approach inherently realizes distributive computing, while also improves the overall efficiency of utilization of the transportation capacities.

4. Possibilities of optimization inside the model

4.1 Possible approaches

Regarding the optimization inside virtual organizations, we can distinguish between centralized and decentralized optimization methods [8.]. The centralized methods, as their name suggests, are based on the centralized distribution of the organization's resources. In some ways, the combinatorial auction mechanism can also be categorized into this type of methods, as in this case, the customer chooses the optimal offer from the numerous bids of the suppliers or service providers. This type of approach has many advantages, but has some weaknesses too. Most notably, in such mechanisms, it is hard to achieve cooperation among the different suppliers and service providers [8.].

The decentralized optimization methods seem to be more suitable for implementation in a holonic organizational environment, as they are naturally based upon distributive computing architectures. In such methods, the solution usually emerges as the result of a complex negotiation process among different autonomous agents. Many theoretical and practical models follow this approach, but their complexity prevented their widespread adaptation in the industry so far.

In the following chapter, a somewhat different method will be introduced, which tries to integrate the centralized and decentralized approaches into a single mechanism (which is a special type of combinatorial auction). By this way, the work distribution among the carriers could be significantly increased, while the main process could still be easily handled.

4.2 A proposed optimization method

The main characteristic of the forthcoming method is that it allows for the lanes to be served by multiple carriers. This is achieved through the handling of the offered transportation capacities as dynamic variables through the optimization process, such that can be modified within certain limit values defined by the given carrier. However, it is important to note that the combinatorial bids are only valid in their complete form, therefore the lower limit of the offered capacity has to be accepted on each lane which the carrier applied for, otherwise the complete bid will become rejected.

The point of the previously outlined process is that it combines the resources of the bidding carriers according to the needs of the shipper. However, the willingness for cooperation on

the carriers side is an important factor in the process, as they define the variability of the offered capacities. Therefore, the effectiveness of the system will mainly depend on the flexibility of the carriers.
For the shippers, the primary advantage of the presented method is that if the performance of one of the assigned carriers gets temporarily reduced, another carrier that is present on the affected lane(s) could easily compensate for the missing performance. Furthermore, this approach would also ensure that the shipper could not get into a position where it would overly depend from a limited number of carriers. From the aspect of the carriers, the method would mainly benefit the small-and medium sized service providers, as through this approach, they could enter into lanes which would be unattainable for them otherwise.
Besides the previous advantages, the system would also contribute to the more efficient utilization of the available resources of the participating carriers, which eventually culminates into better energy management for the whole system. This aspect of optimization has outstanding significance today, when the increasing energy and fuel prices represent a major barrier for the developing economies, especially for countries and regions which depend heavily on foreign energy sources. Thus, the realization of the proposed model not only increases economic efficiency, but also reduces energy dependency and environmental load inside the freight forwarding industry.
As it was mentioned before, in order to keep the trust of the customers, it could be necessary to bound the vendor's entry into the market to certain quality requirements. Moreover, modifying factors can be deduced from the quality performances of the vendors, which can be applied for a complex evaluation of the incoming bids. Such factors can be the state of development of the carrier's information system (i), the reliability that characterize the carrier (r) and the punctuality that characterize the carrier's operations (p). The values of these factors can be determined according to a predefined scale. Of course, these were just a few examples and numerous other factors can be introduced for the purpose of evaluating the bids of the carriers.
It could be also necessary to formulate certain requirements for the shippers as well, such as the precise disclosure of information related to their assignments. This can be important from the aspect of the carrier's, as they can only utilize their resources effectively if they are aware of the exact transportation demands on the individual lanes. These demands can be expressed with the amount of material flow work that are expected by the shipper on the individual lanes (given for example in tons/day, tons/week, tons/month, or in other similar format).
Naturally, numerous other parameters have to be defined in connection with the transportation demand on a given lane (like the types of the applicable unit load carriers, the types of the applicable vehicles, the types of the transported goods, etc.), but these questions are not investigated in the current paper. Instead, the paper continues with the mathematical composition of the presented method.
The first step is the formulation of the auction call by the customer (shipper), which could be done in the following format:

$$S = \left\{ \left[l_{xj}, l_{yj}, l'_{xj}, l'_{yj}, q_{szj}, t \right] \right\}, \quad j = 1,2,...m$$

where:

l_{xj}, l_{yj}	the geographical coordinates of the starting location of the j[th] route,
l'_{xj}, l'_{yj}	the geographical coordinates of the ending location of the j[th] route,
q_{szj}	the nascent transportation capacity requirement on the j[th] route (given for example in tons/week),
t	the duration of the assignment.

The carriers send their bids in response to the auction call. Ideally, each bid is constructed with the help of the jointly used route-optimization software, while all the necessary data is provided by the customer. The bid structure of the carriers is that of the following:

$$F_i = \{[q_{ij}, q_{Min\,ij}, q^F_{ij}, c^F_{ij}], b_i\}, \quad j = 1,2...m$$

where:

F_i	the bid of the i[th] carrier, i=1,2,…n,
q_{ij}	the total amount of the transportation capacity which the i[th] carrier offers for the j[th] route (zero value is allowed),
$q_{Min\,ij}$	the amount of the transportation capacity offered by the i[th] carrier for the j[th] route which the customer has to accept in order to keep the bid of the i[th] carrier,
q^F_{ij}	the standard unit of transportation capacity that serves as the basis of freightage calculation at the i[th] carrier and for the j[th] route,
c^F_{ij}	the i[th] carrier's specific freightage, defined for the j[th] route and for the given time interval, in other words the cost of a single unit of transportation capacity,
b_i	logical variable that defines the actual status of the i[th] carrier's bid during the process of optimization (it equals to 1 if the bid is part of the solution, and it turns to zero if the bid is rejected).

Now we can define the objective function that has to be optimized and which minimizes the costs of the customer:

$$C = \sum_{i=1}^{n}\sum_{j=1}^{m} I_i * r_i * p_i * c^F_{ij} * \left\lceil \frac{q_{ij} - \Delta q_{ij}}{q^F_{ij}} \right\rceil * t * b_i = \min!$$

It can be seen that the previously defined quality factors (I,r,p) are also introduced into the objective function with the aim of correcting the prices of the bids during the process of optimization. The boundary conditions assure the realization of the previously described mechanism of resource allocation:

$$q_{Min\,ij} \le q_{ij} - \Delta q_{ij} \le q_{ij} \quad | \forall i, j$$

$$\sum_{i=1}^{n} \left(q_{ij} - \Delta q_{ij}\right) * b_i = q_{SZ\,j} \quad | \forall j$$

5. Summary

The paper presented the utilization of electronic marketplaces inside the field of logistics, more precisely inside the freight transport industry. Besides the theoretical summary, the second chapter also provided practical examples from this field, based on international studies and literature.

In the second part of the paper, the concept of the E-marketplace integrated virtual transport enterprise was defined, which could be a possible solution for overcoming the difficulties connected to the creation of virtual logistics organizations. The main advantage of the

proposed model is that it integrates the aspects of both central and local planning, while it ensures the decision autonomy of the individual units of the organization.
Finally, the paper proposed an optimization method for the system, one that uses elements of both the centralized and decentralized optimization paradigms. The utilization of this optimization process might contribute to the increase of the overall flexibility and effectiveness of the presented organizational structure, while it could also decrease the levels of energy dependency and environmental load inside the virtual organization.

Acknowledgement
"This research was carried out as part of the TAMOP-4.2.1.B-10/2/KONV-2010-0001 project with support by the European Union, co-financed by the European Social Fund.”

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