COMEX: COMBINATORIAL AUCTIONS FOR THE INTRA-ENTERPRISE EXCHANGE OF LOGISTICS SERVICES

Oleg Gujo
Institute of Information Systems, J. W. Goethe University
Mertonstrasse 17, D-60054 Frankfurt, Germany

Michael Schwind
Business Information Systems and Operations Research, Technical University Kaiserslautern
Erwin-Schrödinger-Str. Geb. 42, D-67663 Kaiserslautern, Germany

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Abstract: The exchange of cargo capacities is an approach that is well established in the practice of logistics. Few of these mostly web-based market places, however, are able to take synergies into consideration that can be generated by the appropriate combination of the transportation lanes of different carriers. One way to achieve this is to employ combinatorial auctions, that allow one to bid on bundles of lanes. This article describes a combinatorial auction for the intra-enterprise exchange of logistic services. In the real world case considered here, we implement and analyze such an exchange process in an enterprise that is related to the food sector and organized in a profit center structure. In the intra-enterprise exchange process, each profit center is able to release delivery contracts for outsourcing if the geographic location of a customer allows a reduced-cost delivery by another profit center in the neighborhood. The cost calculation is based on the results of an integrated routing system, and the in and outsourcing process is managed by using the auction mechanism *ComEx*. For the purpose of customer retention the delivery contracts are kept by the corresponding profit center, the incentive for exchanging the customers is achieved by a cost-savings distribution mechanism. After a description of the web-based logistics auction together with the route optimization system *DynaRoute*, the article describes the search for a cost optimizing strategy that bundles the appropriate delivery contracts.

1 INTRODUCTION

For several years combinatorial auctions (CA) have been gaining increasing influence as an application method in procurement and resource allocation processes. Driven by the development of mechanisms for the allocation of bandwidth in the frequency spectrum to telecommunication service providers in the UK[1], Germany, and the US[2], CAs came into the focus of *electronic market engineering* (McMillan, 1995). This article is concerned with an electronic CA for the exchange of delivery contracts in a medium-sized enterprise which is organized in a profit center structure. The profit centers, which are assigned to regional delivery areas are able to release a delivery contract to an adjacent profit center if the delivery cost situation is unfavorable for this contract. For the purpose of incentive compatibility, the cost savings achieved will be distributed according to a previously defined allocation scheme. The issue of this work is the question of the effective bundling and pricing of transportation contracts, such that the interaction of the local route optimization of the profit centers and the CA will be optimal with respect to the delivery time windows.

[1] http://www.ofcom.org.uk/consult/condocs/spectrum_award/
[2] http://www.fcc.gov

2 COMBINATORIAL AUCTIONS IN LOGISTICS

One of the first approaches to introducing the application of CAs in the logistics sector was made by (Caplice, 1996). (Caplice and Sheffi, 2003) com-

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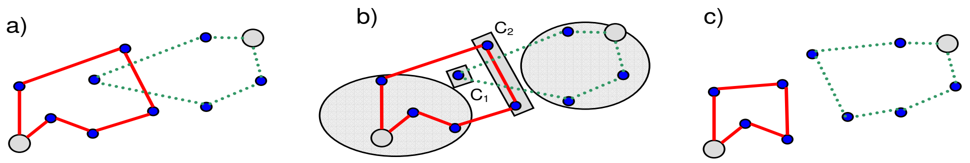

Figure 1: Exchange of customers among two neighboring profit centers.

bine a route planning process with the allocation of transportation capacity by using a CA that selects the cost-minimal combination of delivery contracts. A related approach has been proposed by (Regan and Song, 2003) who suggested a spot market for logistic services that are in excess supply or required in the short-term. A model published by (Pankratz, 1999) leads in the same direction, however, the focus is more on incentive compatibility for the bidders. Some providers of logistics software and operators of freight exchanges have already introduced simple CA mechanisms into their route planning and freight allocation methods.[3] (Elmaghraby and Keskinocak, 2005) document a two-step procurement auction for transportation capacities that has been organized by the home improvement chain *Home Depot* to ensure the logistics supply of about thousand stores. In cooperation with *i2-Technologies* a flexible auction software was developed to support the bidders in formulating the appropriate bid combinations which provide the optimal synergy effects between the routes. The formulation of bid bundles is a critical point in CAs, because it represents a combinatorial optimization problem that cannot be solved without technical support (Schwind, 2005). For this reason, the *ComEx* system presented here is designed to make the in and outsourcing decisions automatically in combination with the bundling of the bids for transportation contracts supported by the *DynaRoute* optimization system provided by our start-up company *VARLOG*[4].

3 FUNCTIONAL AND SYSTEM DESCRIPTION OF *COMEX*

In the following we provide an overview of the functional principle of the CA for logistics services exchange and present the interaction of the auction and optimization process in the *ComEx* system. Fig. 1 depicts the exchange process between two profit centers. The scenario is close to that presented in a recent approach by (Krajewska and Kopfer, 2006), which is also based on a profit center structure and makes use of the matrix auction (Gomber et al., 1999).

Each profit center disposes of an individual set of customers. For simplicity, these customers have already been assigned to a preliminary delivery route (see Fig. 1a). Thereafter a decision is made, based on the geographical location, which customers should definitely remain in the delivery process of the outsourcing profit center. These customers are assigned to the ‘fixed area’ (see Fig. 1b ellipses shaded in gray). The remaining customers are merged into clusters with respect to the geographical location and the delivery time window (see Fig. 1b, cluster C_1 containing one customer, cluster C_2 containing two customers). For each cluster, the cost that could be saved by outsourcing all customer delivery contracts to a neighboring profit center, is calculated. Then an information interchange is performed among the profit centers aimed at defining the outsourcing candidates of some neighboring profit centers as insourcing candidates of the other profit centers. Subsequently each profit center investigates whether the insourcing candidates fit into the existing delivery routes according to delivery time and geographical position. If this is the case, the difference in delivery cost is calculated by including and excluding the set of customers that is added by insourcing the candidate cluster. This difference in cost is then used as the bid price of a cluster while performing the *ComEx* auction. A bid in the *ComEx* auction can also consist of more than one cluster. After each profit center has submitted its bids the CA takes place, searching for the optimal allocation of bids to profit centers that minimizes the total delivery costs in the enterprise. After the closing of the auction the transportation routes will be recalculated based on the information about the customers that have been assigned to it in the final allocation (see Fig. 1c).

The *ComEx* system consists of four components: the *ComEx* server that controls the entire auction process, the *ComEx* engine, which is responsible for the calculation of the optimal allocation, the *ComEx* clients that administer all customers in the delivery area of a profit center while formulating, submitting and receiving in and outsourcing bids, and the *DynaRoute* server that provides the optimal routing information and the associated cost of delivery. In the

[3] www.combinenet.com, www.i2.com, www.nex.com
[4] www.varlog.de

following we describe the interaction of the system components in the four phases of the *ComEx* auction:

- *Initialization phase*: Auction format settings, registration, and licensing data of the participants are transmitted to the *ComEx* server ① using a special XML format CAMeL (Schwind et al., 2004).
- *Outsourcing*: For each profit center the customers are grouped into the clusters taking the time windows and the geographical position into account. The outsourcing candidates are selected based on their distance from the profit center $\boxed{B}$. For each cluster a request is sent ② to the *DynaRoute* server to determine the costs which can be saved by outsourcing the included customers $\boxed{A}$. The information about the outsourcing candidates is sent by every profit center to the *ComEx* server. The profit centers receive the list of clusters which are designated to be outsourced ③.
- *Insourcing*: Every *ComEx* client examines for each profit center whether the insourcing candidates can be added to the existing set of customers while taking their temporal and geographical relation to the remaining customers into account $\boxed{C}$.

  If insourcing is possible, another request to the *DynaRoute* server ④ is sent in order to calculate the additional delivery costs $\boxed{A}$. This information is used as the bid price of a cluster. The *ComEx* server collects these bids, which are passed over by the clients ⑤ and initiates the CA ⑥. An optimal allocation is determined $\boxed{D}$ and the profit centers are informed about the results ⑦.
- *Final assessment phase*: The route plans are updated⑧$\boxed{A}$ and the cost savings in the enterprise are calculated⑨.

3.1 *DynaRoute* Server

Each *ComEx* client has to solve an instance of the *Time Dependent-Stochastic Capacitated Vehicle Routing Problem with Time Window* (TD-CVRP-TW) which extends the $\mathcal{NP}$-complete *Vehicle Routing Problems with Time-Windows* by driving times that depend on the time of day and different categories of time windows. Case studies show that the time window's start can vary to a certain degree while leading an acceptable optimization result. The degree to which a tour does not comply with the time windows is penalized in evaluation function. By using *DynaRoute* the clients are able to optimize their individual tours (Wendt et al., 2005). The optimization algorithm of the *DynaRoute* server is an extended version of *Cooperative Simulated Annealing* (COSA), an combination of the meta-heuristics *Simulated Annealing* (SA) and *Genetic Algorithms* (GA) proposed by (Wendt, 1994). Due to the high complexity that results from the TD-CVRP-TW the COSA algorithm is extended by several concepts to improve performance:

- *Compression of the solution space:* Due to the fact that the evaluation function of the TD-CVRP-TW consumes considerable time cycles, the performance of the algorithms can be increased by excluding solution candidates by using stochastic stop criteria when evaluating new candidates. Moreover, *DynaRoute* identifies patterns by using algorithms similar to ant systems (Bullnheimer et al., 1999) to direct the search to efficient 'regions of the search space'.
- *Tabu-lists:* In the context of SA algorithms the use of tabu lists resulted in a considerable improvement of the performance (Li and Lim, 2003). By using tabu lists (Glover, 1986) *DynaRoute* is able to temporarily exclude solutions or solution regions from the search space. This results in greater diversity of the search process and thus in a higher probability of finding the optimal solution.
- *Approximation of the fitness of inferior solutions:* By reducing the time required for the process of solution evaluation the overall performance of the algorithm can be considerably improved. An exact evaluation of the candidates is not always necessary but can be replaced by an approximation if the accuracy of the approximation is within certain limits. The *DynaRoute* uses the dynamic approximization rules, which adapt the accuracy of the evaluation depending on the progress of the optimization process.

In the context of the *ComEx* framework the *DynaRoute* server optimizes the client specific TD-CVRP-TW and approximates the cost of in and outsourcing customer clusters. The *ComEx* client specifies existing clusters of customers or provides new ones. Based on the generated population of solutions the *DynaRoute* server approximates the impact of these clusters on the cumulative costs of the tour. By running a short reactivation of the optimization process it is possible to integrate or exclude the given clusters in a new 'near optimal' solution. In this way, the cost of adding a new cluster or the savings made when removing a cluster can be very quickly calculated by comparing the original solution to the new solution. The population-based approach allows the server to check the *k*-best solutions of both populations, which provides a strong indicator of the opti-

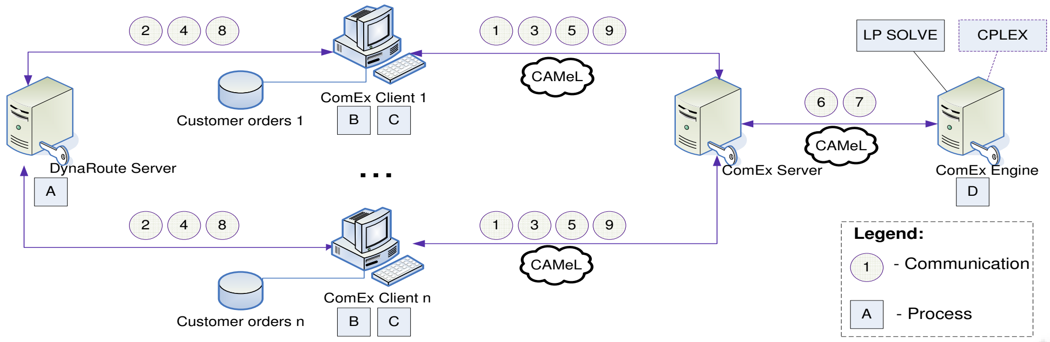

Figure 2: Communication and process flow in the ComEx system.

mality of the solution. This strongly reduces the risk of wrong calculations by minimizing the error that may occur for a single solution due to a 'weaker optimization'. This enables the *DynaRoute* server to deal with the complex cost estimates for the clusters identified by the *ComEx* client.

3.2 *ComEx* Client

For each delivery contract each profit center i decides whether to keep the customer in the set of contracts that should be served anyway or to release the customer to the outsourcing process. In the former case the customers are located geographically close to the particular profit center. As already mentioned above, such customers define the 'fixed area' P_i^f. The remaining customers are assigned to the 'outsourcing area' P_i^o.

3.2.1 Clustering and Outsourcing

The clustering process aims to reduce the complexity of the underlying combinatorial optimization problem and to identify synergies amongst the particular delivery contracts. To achieve this, customers are first ranked according to their geographical position and their delivery time window and subsequently clustered. In our context a cluster C_i^y defines an undirected path, that can be part of a route, that will be determined by a planning algorithm later on. The clustering is independent of the route planning process and aims to group customers that are located geographically close together such that they can be served by a single delivery vehicle with respect to the delivery time constraints. At the beginning of the clustering process each path includes only one single customer. In order to find as many combinations as possible, two strategies are employed in two consecutive phases. During the first phase the clustering algorithm tries to extend a path at its beginning or end by attaching another path to it. In the second phase the clustering

ClusteringFirstPhase(V,E)
1 $E' := \{\{a_k, b_l\} \mid a_k \in C_i^a, b_l \in C_i^b, |\{a_k, b_l\}| \leq r\}$;
2 Sort E' according to increasing distance $|\{a_k, b_l\}|$;
3 **for all** $\{a_k, a_l\} \in E'$ *(* sorted *)*
4 **do if** $((a_k$ end node $\wedge$ b_l end node $) \wedge$
5 $(a_k \wedge b_l$ not in the same cluster $))$
6 **then** bind both clusters with $\{a_k, b_l\}$;
7 **if** (combined cluster is valid)
8 **then** save combined cluster C_i^y;

Figure 3: Clustering algorithm: phase one.

algorithm tries to include a path into another. Let E be the set of edges, V the set of vertices in an undirected graph G while $e_{new} = \{a_k, b_l\} \wedge a_k, b_l \in V$ is a pair of customers a_k and b_l and $|e_{new}|$ defines the distance between them. To illustrate the algorithm of phase one, Fig. 3 depicts the corresponding pseudo code.

Initially the algorithm identifies the set of connections that can be constructed by employing the permutations of all pairs of customers a_k and b_l in the profit center area. This process considers only these customers, that are located within a maximum distance r to each other (line 1). The customer pairs are sorted according to the inclining distance (line 2). The pairs will be considered by the algorithm following this order (line 3). If the customers a_k and b_l of such a pair are both terminal points of two disjoint clusters, a cluster will be constructed by concatenating them by a new edge (lines 4 to 6). Subsequently the validity of the newly generated cluster is checked. The validity of a route is exactly given if the customers of a cluster can be served by using one delivery vehicle within the given time windows by choosing at least one of both possible directions. If validity is given, the route will be saved (lines 7 and 8).

The algorithm of the second phase aims to incorporate existing clusters into others. This means that the route of a cluster is interrupted to integrate the customers of another cluster. Only if this has happened, the processing of the original route is continued by the algorithm. For the integration process of a cluster

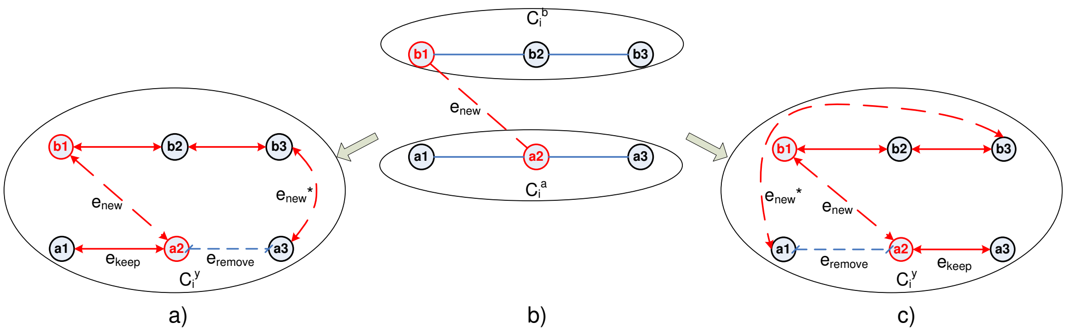

Figure 4: Two variants of clustering: a) first insertion variant b) initial situation c) second insertion variant.

into another cluster, two variants depicted in Fig. 4 are conceivable.

In the beginning a connection between an end node of the first cluster and an inner node of the second cluster is established (see Fig. 4 b). Now two potential connections are determined that allow the inclusion of the first cluster C_i^b into the second cluster C_i^a (Fig. 4 a, 4 c). In analogy to the first phase, the newly created path must not include a connection that has a length greater than r.

Fig. 5 shows the second phase of the clustering algorithm. Initially an empty set E'' is generated (line 1) and successively filled by investigating each element of E' to see whether it is capable of representing the first of two potential connections between both clusters (lines 2 to 3). This is the case if customers a_k and b_l are not included in the same cluster and exactly one of the customers represents a terminal point of a cluster (lines 4 and 5). After determining both variants for the second connection (lines 6 and 7) the corresponding tuple of edges is added to the set E'' (lines 8 to 10).

Subsequently the elements of the set E'' are ordered according to their total distance (line 11) and a verification is made whether the tuple of edges leads to a valid integration of a cluster into another cluster (lines 12 to 16). If the validity of a cluster is guaranteed the cluster is stored (line 17 and 18).

Let $I \in \mathbb{N}$ be the number of profit centers in the enterprise. For each profit center i the customers are sorted into two groups according to their geographical distance to the profit center: a defined percentage of customers with a distance far from the profit center is assigned to the outsourcing area P_i^o, the remaining customers that are closer to the profit center constitute the 'fixed area' P_i^f. For each profit center i a set C_i is formed that contains all clusters in P_i^o that have been formed for profit center i. Each profit center communicates the set C_i to the *ComEx* server that groups the sets to $C^* = \bigcup_{i=1}^{i} C_i$. Finally the set C^* is communicated to all profit centers.

ClusteringSecondPhase(V,E)
1 $E'' := \emptyset$;
2 $E' = \{\{a_k, b_l\} | a_k \in C_i^a, b_l \in C_i^b, |\{a_k, b_l\}| \leq r\}$;
3 **for all** $e_{new} = \{a_k, b_l\} \in E'$
4 **do if** ((a_k inner node $\wedge$ b_l end node) $\wedge$
5 ($a_k \wedge b_l$ not in the same cluster))
6 **then for all** $e_{keep} = \{b_l, b_{l^*}\} \wedge$
7 $l \neq l^* \wedge b_l \in e_{new}$
8 **do** determine e^*_{new}, e_{remove},
9 $\Delta = |e_{new}| + |e^*_{new}| - |e_{remove}|$,
10 $E'' \leftarrow (e_{new}, e_{keep})$
11 $sort(e_{new}, e_{keep}) \in E''$ in according to Δ
12 **for all** $(e_{new}, e_{keep}) = (\{a_k, b_l\},$
13 $\{b_l, b_{l^*}\}) \in E''$(* *sorted* *)
14 **do if** $(a_k, b_l, b_{l^*}$ not in the same cluster)
15 **then** Integrate C_i^a according to the
16 edges e_{new}, e^*_{new}, and e_{keep} into C_i^b;
17 **if** (combined cluster is valid)
18 **then** save combined cluster C_i^y;

Figure 5: Clustering algorithm: phase two.

3.2.2 Bid Formation and Insourcing

Relevant literature describes multiple variants of bidding languages and related bidding languages (Nisan, 2000). The *ComEx* system uses a OR-of-XOR bid logic. This means that XOR-bundles facilitate the formulation of bid combinations that are exclusively selectable, while OR bundles allow for the selection of more than one alternative bid bundle.

Due to its size the number of elements in C^* must be reduced to limit computational effort. This reduction is achieved by removing clusters with a large distance from the insourcing profit center from the set C^* of customer candidates. Subsequently the reduced set C_i^* is used by the insourcing profit center to construct new combinations while merging clusters of its own customer set with clusters of the other outsourcing profit centers (this is done by using the clustering method described in section 3.2.1). Finally the bids of a profit center are constructed as follows: Let $M_i \in \mathbb{N}$ be the number of clusters $C_i^y \in C_i^*$ that are

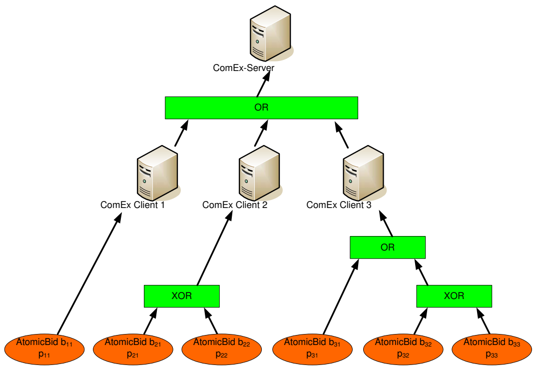

Figure 6: Bid formation logic of *ComEx*.

available for insourcing into profit center $i \leq I$, then $b_{ij} = C_i^{\alpha} \wedge C_i^{\beta} \wedge \ldots \wedge C_i^{\delta}, \alpha \neq \beta \neq \delta \wedge \alpha, \beta, \delta \leq M_i \wedge j \in \mathbb{N}$ is defined as atomic bid of profit center i. For each atomic bid b_{ij} a request is sent to the *DynaRoute* server to determine the delivery costs associated with this bid. At this point, we will not discuss the game theoretic implications concerning truthful bidding and incentive compatibility, because the delivery costs that provide the basis for the formation of the bid prices in each profit center are calculated solely by the *DynaRoute* server and are therefore difficult to manipulate (Schwind, 2005).

Let B be the composition of all bids of a profit center that are linked by the logic operators OR or XOR. Different atomic bids of a profit center may include the same clusters. In this case bids have to be linked by XOR operators. If the subsets of atomic bids are disjoint, the OR operator is employed to link the bids, e.g. $B_3 = b_{31} \vee b_{32} \oplus b_{33}$(Fig. 6).

The *ComEx* system provides a graphical user interface to support the profit centers in administering the customers and visualizes the optimization result. Each profit center holds a table of customers that contains the information required for their administration, e.g. the geographical position of the customer. Customers that should be definitely kept in the set of delivery contracts that are served by a profit center (e.g. for the reason of a high turnover), can be labeled and thus assigned to the area of fixed delivery contracts. After initiating the route optimization process the results of the particular optimization steps are successively visualized by the system (e.g. the outsourcing of released clusters, the bid prices calculated for the released cluster bundles, or the delivery contracts taken over from other profit centers). After the optimization process is finished, the *ComEx* system indicates, how much cost has been saved within the enterprise by employing the CA exchange process, in relation to the sole application of *DynaRoute*. The final route optimization result based on the new customer allocation is visualized on a map.

3.3 *ComEx* Server

The *ComEx* server has the task of controlling the auction process. The *ComEx* server receives the bids submitted by the profit center via web-based requests by using a servlet. The information interchange between the clients and the *ComEx* server is handled using SOAP messages. Our system allows the transmission of messages using the XML-based language CAMeL, that has been designed for the standardized submission of bids in CAs (Schwind et al., 2004). The bids of all profit centers are stored in a data structure $B^* = B_1 \vee B_2 \vee \ldots \vee B_I$ (see Fig. 6). All SOAP messages are encrypted using SSL technology during the transmission process in the web. The bids of all profit centers are stored in a corresponding data structure and are transferred to the *ComEx* engine where the calculation of the CAP is initiated. The resulting optimal allocation is reported to the *ComEx* clients via the *ComEx* server. Additionally, the *ComEx* server calculates the cost savings for the entire enterprise resulting from the application of the CA.

3.4 *ComEx* Engine

As already mentioned, the *ComEx* server forwards the bids B_i of each *ComEx* client i to the *ComEx* engine employing CAMeL messages. In order to find the optimal allocation the *ComEx* engine solves the combinatorial auction problem (CAP) (Vries and Vohra, 2001). Let z be delivery costs in the enterprise, M the set of all clusters to be allocated to the profit centers, J_i the number of all bids of profit center i, and $b_{i,j}(C_v) = 1$ if atomic bid $b_{i,j}$ contains cluster C_v, then the CAP for the combinatorial exchange linked to the construction of optimal tours can be formulated:

$$min\ z = \sum_{i=1}^{I} \sum_{j=1}^{J_i} p_{ij}\, x_{ij} \qquad (1)$$

$$\sum_{i=1}^{I} \sum_{j=1}^{J_i} b_{ij}(C_v)\, x_{ij} = 1 \quad \forall C_v \in C^* \wedge x_{ij} \in \{0,1\} \qquad (2)$$

$$b_{ij}(C_v) = \begin{cases} 1, & \text{if } C_v \text{ in } b_{ij} \\ 0, & \text{otherwise} \end{cases} \quad \forall C_v \in C^* \qquad (3)$$

The acceptance variable x_{ij} indicates whether a bid should be accepted or not and guarantees that the integer condition is maintained. Equation (2) assures that all clusters appear in the final allocation.

The open source software package LP_SOLVE 5.5 is used to solve the CAP. The package provides an exact solution of the $\mathcal{NP}$-complete problem for up to hundreds of bids within acceptable computation time. For higher problem complexities the use of heuristics is recommendable (Schwind and Gujo, 2005).

4 THE IMPACT OF CLUSTERING PROCESS ON DELIVERY COSTS

The main objective of the *ComEx* system is to provide a significant reduction of delivery costs for the entire enterprise. This can only be achieved if a suitable strategy for the preparation of bids in the in- and outsourcing of delivery contracts is applied. In our framework two impact factors are of importance: The maximum distance r between two neighboring customers within a cluster that forms a possible section of a delivery tour and the percentage a of clusters that definitely remain under the service of a profit center. Additionally, the impact of the pricing method for bids submitted by each profit center is of interest with respect to the total delivery costs. For the simulations the parameters were varied within the following limits:

- Maximum distance r between two customers in a cluster: $2-20$ km (steps of 2 km)
- Percentage a of clusters in the outsourcing area: $20\% - 100\%$ (steps of 20%)

The simulations were repeated multiple times to reduce the stochastic effects that result from the use of the heuristic procedure in the *DynaRoute* tour optimization process.

Fig. 7 shows that a maximum distance of $r = 10$ km between the customers in a cluster and a percentage a of 40% of clusters in the outsourcing area yields the largest reduction in overall transportation costs. If the maximum allowed distance r is set to a high level in the bid preparation process, the single clusters contain only few customers. This means that the transfer of customers can only cause small synergy effects.

On the other hand, if the maximum allowed distance r in the clustering process is set to a high value, very complex clustered tours are released into the outsourcing process. Such clusters are difficult to integrate into the existing tours of the other profit centers.

The second simulation method strives to achieve computational time savings by omitting the *DynaRoute*-based calculation of delivery costs for each outsourcing candidate. Instead, for each cluster the

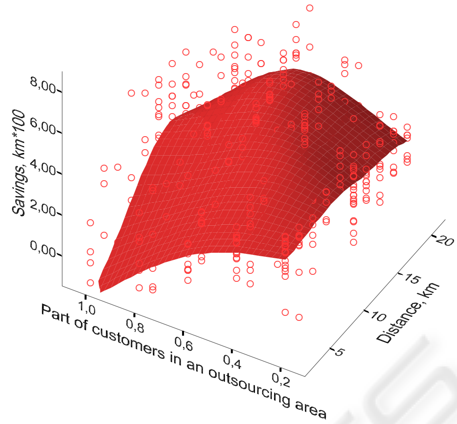

Figure 7: Reduction of delivery costs by the application of the *DynaRoute*-based stategy (first simulation).

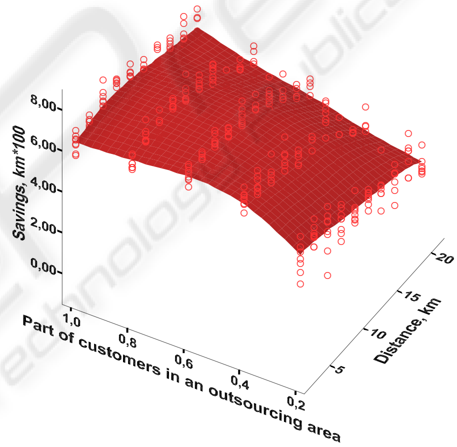

Figure 8: Reduction of delivery costs by the application of the distance-based strategy (second simulation).

average of distances between the customers and the profit center is used to estimate the bid price. All other simulation settings are kept identically to the previous simulation. Fig. 8 shows that a maximum distance of $r = 10$ km between the clients in a cluster and a percentage a of 60% of clusters in the fixed area lead to the largest reduction in transportation costs in the entire enterprise. The differences between the simulations occur because in the first case the integratability of a cluster into an existing route is crucial for the pricing of the bids. Obviously, pricing using a distance estimate performs significantly for a large set of outsourcing candidates and small distances in the clusters (Fig. 8 lower left). By contrast, if the concatenation of customers to longer clusters is allowed, the combinatorial complexity of CA-based tour recombination is dominant. This leads to a slightly better performance of *DynaRoute*-based pricing (Fig. 7 upper middle). The results indicate that bid formation must be improved.

5 CONCLUSION

This paper presented the software system *ComEx* for the auction-based exchange of transportation services in connection with the route optimization system *DynaRoute*. The evaluation focuses on the search for an optimal mechanism that helps to formulate the appropriate in and outsourcing bids for the transfer of delivery contracts between neighboring profit centers, such that a transportation cost reduction results for the entire enterprise. By using real world delivery data from an enterprise in the food industry, an optimal maximum distance of 10 km between two neighboring customers in a cluster and an optimal fraction of 40% (60% in case of the second simulation) of customers kept in the fixed delivery area have been identified. Further, our *ComEx* mechanism has a much greater importance for the exchange of transportation services between independent enterprises than for the intra-enterprise sector, e.g. as a general combinatorial freight exchange. Such a realization of a logistics marketplace, however, raises questions about an incentive compatible method for evaluating the bids, for example the *Vickrey-Clarke-Groves* mechanism. In our case, this problem has been circumvented by the use of identical automated bid construction mechanisms for all participants. However, the question of a fair and incentive compatible distribution of the cost savings between the profit centers remains. Together with the implementation of a general exchange for logistic services together with a major logistic provider, and the improvement of the clustering and pricing mechanism, this will be the next issue in our research.

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