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PROCUREMENT OF TL TRANSPORTATION  
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# Reputation-based Winner Determination Problem in Transportation Combinatorial Auction for the Procurement of TL Transportation Services in Centralized Markets

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**ABSTRACT:** *In transportation auctions, shippers can act in a centralized or a decentralized market. This paper compares centralized and decentralized auction in which winning carriers (known as the Winner Determination Problem: WDP) are determined based not only on bid prices but also on carriers reputation. Preliminary results show that such a centralized reputation-based transportation auction is beneficial on two levels. First, it exploits the synergy between the shipping contracts yielding possibly to lower bid prices. Second, it enables an information sharing between shippers on the reputation of the participating carriers to help them have a more accurate judgement on carriers' reputation. The comparison between reputation-based Winner Determination model in a centralized market and the reputation-based Winner Determination model in a decentralized market shows that, with instances of four shippers, they may save 27.4% of their total costs if they participate in a centralized market instead of a decentralized market.*

**KEYWORDS:** *Market Centralization, Combinatorial Auctions, Truckload, Winner Determination Problem, Carrier Reputation.*

## 1 INTRODUCTION

The increasing cost of energy and the rising competition in transportation markets require new strategies of logistics management and force shippers and carriers to optimize their transportation services. Also, modern logistic management gives great importance to environmental concerns and sustainability. Hence, freight transportation face two interrelated challenges, the first is economic and the second is environmental. On one hand, delivery costs have to be reduced and on the other hand inefficiency in freight operations tend to generate more greenhouse gas (GHG) emissions which have to be controlled and reduced (Quariguasi et al.; 2008). One promising solution often used in this context is to avoid useless movement of traffic by optimizing transportation operations in existing transportation networks. The optimization approach is based on combinatorial auctions in transportation markets as trading mechanisms that allow carriers to bid on bundles (also called packages) of lanes (ie, origin-destination pairs). Thus, carriers are able to express their valuations for any collection of lanes they want to acquire. In general, package bidding is beneficial for situations in which complementarity/substitutability effects exists

between traded items. Items under auction are referred to complementary items when the value for a combination of items is greater than the sum of the values for these items taken independently. In transportation market, when freight lanes are *complementary*, they may create greater economies of scope. In fact, a significant proportion of costs in trucking operations is due to the repositioning of empty vehicles from the destination of one load to the origin of a subsequent load (Song and Regan; 2005). To this end, carriers seek a set of lanes that are synergistic with respect to repositioning costs (Lee et al.; 2007) and aim to acquire adjacent lanes and/or lanes that form a closed loop in order to minimize empty backhauls and raise vehicle utilization (Song and Regan; 2005; Lee et al.; 2007). In recent years, combinatorial auctions have been used in several transportation procurement markets where *shippers* and third-party-logistics (3PL) providers (the services askers) and *carriers* (the services providers) trade shipping contracts (Elmaghraby and Keskinocak; 2004). The objective is to reduce their transportation costs during procurement. Elmaghraby and Keskinocak (2002) reported the successful results yielded by combinatorial auction conducted by Home Depot Inc. Additional applications are reported by Logistics.com and in-

clude Wall Mart Stores, Compaq Computer Co, Staples Inc., The limited Inc. and Kmart Corporation. Caplice and Sheffi (2006) provided a summary information on several combinatorial transportation auctions designed between 1997 and 2003. Their synthesis reveals an average saving of 13% in transportation costs.

Combinatorial transportation auctions Transportation auctions often involve one shipper who communicates its shipping requests to a set of competing carriers. In response to shipper requests, each carrier participating to the auction submits a set of bids to the market. A bid is defined by a set of shipping contracts (or more simply lanes) the carrier offers to serve and the price asked for serving all these contracts. The way a carrier combines contracts and determine ask prices is known as the *carrier bid construction problem*. After receiving all carriers bids, the shipper determines winning bids by solving the well-known *Winner Determination Problem* (referred to in the following as WDP). The objective of WDP is to minimize the shipper transportation costs. When only one shipper is involved in the auction and only carriers are allowed to submit bids, the transportation auction is called one-sided (or uni-lateral or one-to-many) auction. Otherwise, another type of procurement auction is called two-sided auctions (or double auctions or multi-lateral auctions or exchanges) in which several shippers participate in the auction and these latter are allowed (like carriers) to submit bids. In this study, we consider a combinatorial transportation auction in centralized market which differ from one-sided and two-sided combinatorial transportation auctions. In fact, unlike one-sided auction which is run in a decentralized market and which involve only one shipper, the auction mechanism we propose here involve several shippers who participate in the same auction market (centralized market). Also, unlike two-sided auction which allow shippers and carriers to submit bids, the auction mechanism we propose here allow only carriers to submit bids. Consequently, the proposed mechanism takes advantage of simplicity of one-sided transportation auctions compared to two-sided auctions whereas exploiting combinatorial bidding as a mean to reinforce collaboration between shippers. Shippers collaboration in transportation procurement services through auction mechanism, means that, several shippers run together only one auction rather than one auction for each one of these shippers. Carriers are the only bidders and the objective of the collaboration is to better procure transportation services collectively by reducing carriers costs and increasing profits to carriers and consequently to shippers.

Several studies show the importance of considering attributes other than the price to select carriers. In the literature, a few studies considered service quality aspects in the allocation phase. Recently, Rekik and

Mellouli (2012) proposed a reputation-based WDP model for one-sided auctions including only one shipper. They propose to translate carriers reputation into unexpected hidden costs that represent the possible additional costs that the shipper may incur when dealing with the winning carriers.

The problem we address here is a reputation-based WDP model for transportation combinatorial auctions in a centralized market. The problem is inspired by the work of Rekik and Mellouli (2012) but considers the case where a set of shippers run together the same auction. The main difference is that one should decide on the winning bids knowing that: (1) a same bid may include shipping contracts requested by different shippers and (2) a carrier reputation may differ from one shipper to another. In a decentralized market, each bid is only related to the contracts of the shipper. In a centralized market, a bid may contain a combination of contracts for different shippers. In a decentralized market, a shipper decides based on its own reputation about the bidding carriers. In a centralized market, the auctioneer decides the reputation of the bidding carriers based on different valuations of the shippers participating in the auction.

We consider truckload (TL) transportation markets. Unlike less-than-truckload operations (LTL) where shipments are consolidated in terminals and hubs, TL shipments must be driven directly from pick-up to delivery locations without any intermediate stop. Caplice and Sheffi (2006) reported that TL segment represents more than 78% of the total trucking transportation market in the USA.

In this paper, we propose a new reputation-based Winner Determination model in a centralized market. We develop three different strategies to compute the reputation in a centralized market. We compare, these strategies with the reputation-based Winner Determination model in a decentralized market. Results show that, with instances of four shippers, they may save 27.4% of their total costs (average of the three strategies) if they participate in a centralized market instead of a decentralized market.

The reminder of the paper is organized as follows. Next section is a short literature review on winner determination problem and reputation of carriers in transportation procurement auctions. Section 3 presents the trading context, the assumptions and the different formulations of WDP with reputation in centralized transportation markets. Section 4 presents a case study of reputation computation according to the different proposed formulations. In Section 5, we present our instance generator and give some preliminary results. Section 6 is a conclusion.

## 2 LITERATURE REVIEW

The allocation problem in combinatorial auctions consists in determining the winning bids among those

submitted to the auctioneer. The objective of WDP is to minimize the total transportation cost, subject to the constraint that each lane must be served by one carrier. This problem is called the set-covering problem which is a standard operations research problem (Sheffi; 2004). In the procurement context, the WDP is usually modelled as a variant of a set partitioning or set covering problem, both of which are NP-hard combinatorial optimization problems.

Different approaches of winner determination problems in combinatorial auctions for transportation contracts are treated in the literature. In the explicit approach of truckload procurement auctions, combinatorial auctions have two computational and communication hurdles which are the bid expression/communication and the resolution of the winner determination problem. The source of these hurdles is the exponential number of bundles that must be priced and communicated to the WDP. It is noteworthy that a carrier can compute a bid price for  $2^n - 1$  packages (with  $n$  is the number of lanes submitted by the shippers) and communicate these bids to the auctioneer which will solve an exponentially-sized WDP to prize the packages to bidders.

Caplice and Sheffi (2003) present two models of WDP, the first deal with general WDP taking into account transported volumes and the second deal with WDP with conditional bids.

Guo et al. (2003) and Guo et al. (2006) extend traditional WDP by incorporating shipper business considerations such as restricting carrier numbers, favoring incumbents and performance considerations to the WDP. Representative models and meta-heuristics are developed to solve the WDP. In the same context, van Norden et al. (2006) report that although the objective of the WDP is to minimize the total transportation cost, the shipper may take into account other considerations, such as upper bounds on the number of winning carriers in total, per load location, per country of destination, and the maximal transport volume any carrier is allowed to win (van Norden et al.; 2006).

Ma et al. (2009) and Remli and Rekik (2012) presents stochastic integer programming model for the WDP in a context where shipment volumes are not known with certainty.

Mettichi et al. (2012) proposes an approach for WDP at the operational level while taking into account the decisions made at the strategic level (Mettichi et al.; 2012). Their study presents a general framework including both strategic and operational phases. These phases include mathematical models to optimize WDP computation (Mettichi et al.; 2012).

Gujo (2008) develop a system to solve the WDP taking into account multi-attribute bids. The challenge is to manage the trade-offs between an optimum allocation of bids and satisfaction of shippers preferences. In the explicit approach of truckload procurement

auctions, WDP analysis all possible submitted bids which can be  $2^n - 1$  bids in order to decide winning bids. Cohn et al. (2008) and Chen et al. (2009) have developed an implicit approach of truckload procurement auctions in which the solution of the bid-generating function are embedded directly in the WDP instead of  $2^n - 1$  packages (Cohn et al.; 2008). Cohn et al. (2008) and Chen et al. (2009) have shown that the implicit WDP of combinatorial auctions is more tractable than classic WDP, even for large instances.

All studies dealing with WDP focused on package bidding in order to exploit synergies between contracts and the objective is to minimize the total procurement costs while maintaining high level of service quality. There is usually a trade-off between the cost-minimization goal on one hand and the level of service quality on the other hand (Buer and Pankratz; 2010b). Buer and Pankratz (2010a) and Buer and Pankratz (2010b) and Buer and Kopfer (2011) model the WDP as bi-objective optimisation problem and solved it under explicit consideration of multiple objectives (Buer and Pankratz; 2010b). Except the cost minimisation function, the authors introduced a second objective function for maximizing the transport quality within the WDP. In the same context, Rekik and Mellouli (2012) consider reputation of carriers in the WDP model and propose to translate carriers reputation into unexpected hidden costs that represent the possible additional costs that the shipper may incur if some problems as delay or damage occur.

The shippers collaboration in the procurement of transportation services has received little attention in the literature. It has been studied in Agrali et al. (2008) which consider a single-item auction (do not allow package bidding) and Hosseini Motlagh et al. (2010) who presents the model of double combinatorial auction in LTL transportation procurement. Hosseini Motlagh et al. (2010) report that combinatorial double auctions outperforms combinatorial auctions. Unlike two-sided auctions in which shippers and carriers participate as buyers and sellers and one-sided auction in which only one shipper participates, we consider in this paper a particular trading mechanism in which a set of shippers run in a centralized market only one auction, and a set of carriers compete through a combinatorial auction process by submitting combinatorial bids on shipping movements of all shippers at the same time. This mechanism takes the simplicity of the one-sided auctions in the bidding process and exploit combinatorial bidding as a way to carry out collaboration of shippers. In fact, in the trading process, it is the one-sided combinatorial auction who is considered rather than the two-sided auction. The collaboration strand is reconsidered at the end of the auction process, in the cost allocation problem resolution (CAP). That is, how to decide on the cost to be allocated to each shipper once the auc-

tion ends. Crainic et al. (2009) have already considered such a context for general procurement markets. They report that putting together in the same auction a larger variety of items coming from different buyers would yield an important saving in the total cost to be paid by all buyers, especially when a high level of synergy exists between the traded items. Crainic et al. (2009) do not study the WDP but emphasize on the CAP.

### 3 PROBLEM FORMULATION

Let  $A$ , respectively  $E$ , be the set of carriers, respectively, shippers participating in the auction. Let also  $K(e)$  denote the set of shipping contracts requested by shipper  $e$  and  $K = \cup_{e \in E} K(e)$  the set of all contracts to be auctioned. We consider only long-term TL contracts. Each TL contract  $k$  is defined by a pick-up location  $O_k$ , a delivery location  $D_k$ , a number or frequency of shipments  $N_k$ , and an estimated transported volume for each shipment  $V_k$  (the same for all shipments).

Each carrier  $a \in A$  is assumed to submit a set of combinatorial bids  $B(a)$ . A bid  $b \in B(a)$  is defined by a pair  $(K(b); BP(b))$ , where  $K(b)$  denotes the set of contracts carrier  $a$  offers to serve in bid  $b$  and  $BP(b)$  is the price asked for serving all these contracts. Note that  $K(b)$  may include contracts of different shippers (i.e.  $K(b) \subseteq K$ ).

Let  $\Omega$  denote the set of service attributes considered by the shippers to evaluate carriers reputation. To alleviate the presentation, we assume that there is a consensus already made by the shippers on the attributes to be considered. As already mentioned, Rekik and Mellouli (2012) recently proposed a reputation-based WDP for one-sided transportation procurement markets where a single shipper runs a combinatorial auction and select carriers based on both bid ask prices and carriers' reputation. Our approach is inspired by that proposed in Rekik and Mellouli (2012) in the way carriers' reputation is quantified in terms of potential hidden costs. It extends it to the case where multiple shippers decide to run together a centralized combinatorial auction to benefit from: (1) their contracts synergy and (2) the information they detain on carriers reputation.

Next section recalls the main steps of the approach proposed by Rekik and Mellouli (2012) in a decentralized market (decentralized in the sense that each shipper runs a transportation auction by its own). Section 3.2 presents the extension we propose for the centralized market considered. More details on the different methods proposed to compute carriers reputation in our context are presented in Section 3.2.

### 3.1 Decentralized Reputation-based WDP

Rekik and Mellouli (2012) proposed a generalized set-covering formulation to model the WDP in which the objective function minimizes not only bid ask prices (as commonly proposed) but also what they call unexpected hidden costs. Hidden costs represent the potential additional costs the shipper would incur if the level of service procured by the winning carriers during operations is not satisfactory. To estimate these hidden cost, the authors assume that the shipper relies on the past performance of the carrier (its reputation). Roughly speaking, the reputation of a carrier  $a$  is determined based on a number of services attributes  $\omega \in \Omega$  ( $\omega$  could be for example the on-time delivery performance). The shipper evaluates the value that is expected to be taken by an attribute  $\omega$  for carrier  $a$  based on its past performances. This value is denoted  $\Gamma_{a,\omega}$ . We refer the reader to Rekik and Mellouli (2012) for more details on how historical data can be used to determine such a value. The shipper assigns a cost  $C_{k,\omega}$  for each unit deviation of the value of attribute  $\omega$  that is expected to occur with carrier  $a$  (i.e.,  $\Gamma_{a,\omega}$ ) from the value considered acceptable for the shipper. This cost depends on the contract auctioned (for example, a delay in delivering perishable products is more penalized than non perishable ones). Based on this, the hidden cost,  $HC(a, k)$  associated with contract  $k$  when served by carrier  $a$  is computed as:

$$HC_{a,k} = \sum_{\omega \in \Omega} C_{k,\omega} * \Gamma_{a,\omega}$$

The decentralized reputation-based WDP is formulated using binary variables  $x_b$  defined for each bid  $b \in B$ , where  $B$  denotes the set of all submitted bids (ie,  $B = \cup_{a \in A} B(a)$ ). Variable  $x_b$  equals 1 if bid  $b$  wins; 0 otherwise. A constant parameter  $\delta_{bk}$  is also defined for each contract  $k$  and each bid  $b$  to indicate whether bid  $b$  covers contract  $k$ . That is,  $\delta_{bk} = 1$  if  $k \in K_b$ ; 0 otherwise. The proposed model, (P1), can thus be written as:

$$(P1) : \min \sum_{a \in A} \sum_{b \in B(a)} (BP(b) + HC(b)) * x_b \quad (1)$$

$$\sum_{a \in A} \sum_{b \in B(a)} \delta_{bk} x_b \geq 1 \quad \forall k \in K, \quad (2)$$

$$x_b \in \{0, 1\} \quad \forall a \in A, b \in B(a), \quad (3)$$

where:

$$HC(b) = \sum_{k \in K(b)} HC_{a(b),k}$$

$a(b)$  is the carrier submitting bid  $b$ .

(P1) is a set covering formulation that minimizes the total cost paid by the shipper. This cost includes

both ask price and unexpected hidden costs associated with each submitted bid (Rekik and Mellouli; 2012). Constraints (3.3) guarantee that each contract is covered at least once by carriers bids. Constraints (3.4) are integrality constraints.

### 3.2 Centralized Reputation-based WDP

In a centralized market, shippers put together their contracts and participate into the same auction with the same competing carriers. When combinatorial bidding is permitted, a same bid submitted by a carrier  $a$  may include contracts belonging to different shippers, say  $e_1$  and  $e_2$ , because there is a synergy between these contracts given carrier  $a$  existing network. Such a synergy is due to a reduction in empty moves, for example, and generally yield interesting bid ask prices for both shippers. However, carrier  $a$  could be viewed as a reliable carrier by  $e_1$  and an unreliable one by shipper  $e_2$ .

One can ask the following questions: (1) How to manage the different evaluations of the different shippers towards the same carrier? (2) Is it still beneficial for shippers to collaborate in this case? (3) Should they view this collaboration as an opportunity to adjust the information they have on the carrier performance? or should they view it as a possible deterioration in the quality of services? (4) In the latter case, is the gain in direct costs (the bid ask price) substantial enough to accept a relatively small increase in hidden costs?

The objective of this paper is to address these issues and propose different ways of computing carriers reputation depending on the importance given to the shippers in evaluating the carriers and their bids.

In the rest of the paper, the reputation of a carrier  $a$  provided by shipper  $e$  with respect to the attribute  $\omega \in \Omega$  is denoted  $\Gamma_{a,\omega,e}$ . This reputation is computed based on the formula proposed by Rekik and Mellouli (2012) for the decentralized case. Each shipper  $e$  is also assumed to have an estimation on the cost to be incurred when a unit deviation with respect to an attribute  $\omega$  occurred for contract  $k \in K(e)$ . This cost is denoted  $C_{k,\omega}$  as for the decentralized WDP. Different methods are proposed to determine hidden costs associated with contracts and bids. These methods differ on the importance given to the shippers in evaluating the reputation of participating carriers and their bids.

The hidden cost associated with a contract  $k$  and a carrier  $a$  is determined based only on the reputation of the carrier  $a$  as viewed by the shipper  $e(k)$  requesting this contract. In other words, each shipper  $e$  keeps its value  $\Gamma_{a,\omega,e}$  as it is to evaluate a carrier and its bids.

Consider a bid  $b$  submitted by a carrier  $a \in A$  such

as  $b \in B(a)$  and  $b = (K(b), BP(b))$ . Let  $E(b)$  be the set of shippers having contracts in  $k(b)$  and  $K(e, b)$  be the set of contracts in  $K(b)$  belonging to  $e$ . The hidden cost associated with contract  $k \in K(e, b)$  is given by:

$$HC_{a,k} = \sum_{\omega \in \Omega} C_{k,\omega} \Gamma_{a,\omega,e}$$

The hidden cost that could be incurred by a shipper  $e \in E(b)$  if bid  $b$  wins is given by:

$$HC_{a,b}^e = \sum_{k \in K(e,b)} HC_{a,k}$$

Figure 1 shows that each shipper having contracts in a bid  $b$  gives his hidden cost of his contracts  $HC_{a,b}^e$ . We observe that in such competitive transportation

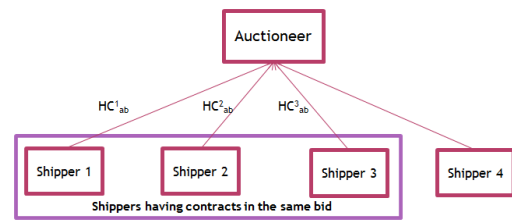


Figure 1: Collaboration in carrier reputation valuation

market, shippers are assumed to collaborate to obtain gains in the direct costs (bid ask prices) but compete with regard to hidden costs, each aiming to have the carrier that offers the best trade-off for him. The auctioneer must thus find a balance between shippers valuations of bids hidden costs. We propose to model this balance by considering a weighted sum of shippers hidden costs.

The generalized mathematical model of the competitive context can thus be formulated as follows:

$$(P2) : \min \sum_{a \in A} \sum_{b \in B(a)} BP_b * x_b \quad (4)$$

$$+ \sum_{a \in A} \sum_{b \in B(a)} \sum_{e \in E(b)} w_{e,b} * HC_{a,b}^e * x_b$$

subject to constraints (2) and (3), where  $w_{e,b}$  is the weight associated with the hidden cost incurred by shipper  $e$  if bid  $b$  wins.

In the following, we propose three ways of determining weights  $w_{e,b}$  depending on the global, local and historical importance of the shipper.

#### 3.2.1 Global importance method

$$w_{e,b} = \frac{|K(e)|}{\sum_{e \in E(b)} |K(e)|}$$

This implies that we are favouring the shipper  $e \in E(b)$  that has the larger percentage of requested contracts (in the whole auction) when compared to other shippers having contracts in  $b$ .

### 3.2.2 Local importance method

$$w_{e,b} = \frac{|K(e,b)|}{|K(b)|}$$

Here, we favouring the shipper that has the larger number of contracts in the bid.

### 3.2.3 Historical importance method

$$w_{e,b} = \frac{|S(e,a)|}{\sum_{e \in E_b} |S_{e,a}|}$$

In this case, we favour the shipper that has the higher level of knowledge of carrier  $a$  submitting bid  $b$  with regard to the other shippers having contracts in  $b$ . This level of knowledge is through the number of shipments contracted in the past with the carrier. Formally, let  $|S(e,a)|$  denote the number of shipments of shipper  $e$  ensured in the past by carrier  $a$ .

## 4 CASE STUDY

We run an auction with carrier  $a1$  and 3 shippers  $e2$ ,  $e5$  and  $e7$ . Table 1 gives some informations about the 3 shippers.

Shipper	$ K^e $	$ S^e $
e2	3	21
e5	6	3
e7	11	67

Table 1: Shipper’s characteristics

Let see For the bid  $b1$  submitted by the carrier  $a1$ , how to evaluate the hidden cost (HC) of the bid in the different methods of weighting.

We propose to evaluate the reputation of a carrier through three attributes (as in (Rekik and Mellouli; 2012)): the shipment delay ( $\omega1$ ), the damaged (lost) shipments ( $\omega2$ ), and the cancelled shipments ( $\omega3$ ). Values of reputation of each carrier towards these attributes as well as the costs associated with each contract  $k$  and the three attributes are randomly generated as in Rekik and Mellouli (2012).

Table 2 shows different attributes of the bid  $b1$ .

We consider that, each shipper gives his valuation of reputation and we weight these valuation with three method. Table 3 shows the different weights of shippers  $e2$  and  $e7$ .

**Global importance method** Multiplying the hidden costs of contracts with the global weights of the

Weighting method	$\psi_{S2,1}$	$\psi_{S7,1}$
Global Importance	0,22	0,78
Local Importance	0,5	0,5
Historical Importance	0,24	0,76

Table 3: Shippers weights in bid  $b1$

shippers we obtain hidden costs of the contracts according to global importance method as shown in Table 4.

K	e	$HC_{ak}$	$\psi_{global}$	$HC_{ak}^{global}$
131	7	1520,119	0,22	334,426
102	2	792,659	0,78	618,274
			Hidden Cost of $b1$	952,701

Table 4: Hidden Cost of  $b1$  according to global importance method

**Local importance strategy** Multiplying the hidden costs of contracts with the local weights of the shippers we obtain hidden costs of the contracts according to local importance method as shown in Table 5.

K	e	$HC_{ak}$	$\psi_{local}$	$HC_{ak}^{local}$
131	7	1520,119	0,5	760,059
102	2	792,659	0,5	396,329
			Hidden Cost of $b1$	1156,389

Table 5: Hidden Cost of  $b1$  according to local importance method

**Historical importance method** Multiplying the hidden costs of contracts with the historical weights of the shippers we obtain hidden costs of the contracts according to historical method as shown in Table 6.

K	e	$HC_{ak}$	$\psi_{local}$	$HC_{ak}^{historical}$
131	7	1520,119	0,24	364,828
102	2	792,659	0,76	602,421
			Hidden Cost of $b1$	967,250

Table 6: Hidden Cost of  $b1$  according to historical importance method

## 5 PRELIMINARY RESULTS

This section gives some preliminary results obtained with the proposed methods. The main objective is to analyse the impact of procurement centralization on shippers direct cost, shippers hidden costs and

K	e	Delay Cost	Reputation Delay	Damage Cost	Reputation Damage	Cancel Cost	Reputation Cancel	HC <sub>ak</sub>
131	7	8,36	0,04	0,82	0,01	283,95	0,08	1520,119
102	2	5,7	0,01	0,27	0,02	141,75	0,1	792,659

Table 2: Bid's characteristics

shippers total costs with the different collaborative approaches defined above. To this end, we compare these total costs to a context where a decentralized procurement is considered. That is, each shipper runs a single auction with the same carriers by its own.

### 5.1 Data generation

Since no real-life instances were available, we randomly generate a centralized transportation market with 4 shippers, 14 auctioned (new) contracts and 4 carriers. Contracts are assumed to require 52 shipments each (weekly delivery). A transportation network is randomly generated for each participating carrier. This network includes all the contracts the carrier already engages on (before the auction) and that it must serve in the upcoming planning horizon. The existing network is then used to determine the new contracts that are profitable for the carrier to bid on in the current auction. This bid construction problem is solved using a constructive algorithm (for more details we refer the reader to Ben-Othmane et al. (2012)).

### 5.2 Results

We run auction with the different combinations of shippers (combinations of 1, 2, 3 and 4 shippers) and the 4 carriers. For each auction we solve the BCP for all carriers and then we solve the WDP to decide the winning bids. We solve the classic WDP (without reputation) and the decentralized reputation-based WDP for the 4 shippers (each shipper runs alone the auction). Also, we solve the WDP with centralized reputation-based WDP for the three method of weighting (global importance, local importance and historical importance). The direct costs (DC), hidden costs (HC) and total costs (TC) paid by the shippers collaborating together (the centralized WDP) is compared to the sum of their costs (DC, HC and TC) when each one of them run an auction alone (the decentralized WDP).

The differences of these costs(in%) computed as  $\frac{[\sum_{e \in E} Cost(decentralized)] - Cost_{e \in E}(Centralized)}{\sum_{e \in E} Cost(decentralized)}$  is presented in the following tables. Table 7 shows the difference in costs for the WDP without reputation. The comparison shows that in most instances, collaboration leads to savings in direct costs. This is due to possible synergies that exists between the shippers

contracts and that yields to lower bids ask prices. In some times there is a loss in direct costs (case collaboration between shipper 1 and 3), this is due to the lack of capacity to serve the two shippers at the same time). But in average, there is always savings in direct costs (shown by the average line). Finally, savings (in average) in direct costs increase by increasing the number of collaborators (the saving of the collaboration of the 4 shippers is better than the average of saving of the collaboration of 3 shippers, which is also better than the average of saving of the collaboration of 2 shippers). The collaboration of four shippers have allowed them to save 9.37% of their costs. Table 8 shows the difference between the sum of costs

Shippers	DC (%)	Non-covered contracts
(1,2)	0,22	0
(1,3)	-0,05	1
(1,4)	8,39	0
(2,3)	0,55	0
(2,4)	2,69	0
(3,4)	7,53	0
Average	3,22	
(1,2,3)	0,44	0
(1,3,4)	10,53	0
(2, 3,4)	6,47	0
Average	5,81	
(1,2,3,4)	9,37	0
Average	9,37	

Table 7: Impact of collaboration on paid costs in a without reputation WDP computation

of the decentralized reputation-based WDP and the Centralized reputation-based WDP with the different methods of weighting. The comparison shows that generally there is a gain in direct cost because of synergies. If it isn't the case, this may due to a lack of capacity (carriers can't satisfy all shippers at the same time, whereas they were satisfied in the decentralized approach(each alone)) or that they pay more in direct cost but save more in hidden costs.

Concerning hidden costs, for most instances, there is a gain in hidden costs,that is when collaborating shippers in the centralized approach adjust their valuations of carriers reputation by reducing the value of the hidden costs. This allows to conclude that shippers in the decentralized approach underestimate the service quality of the carriers and by collaborating they adjust their valuations to the better. For one instance there is a loose in hidden cost. That is shippers



Shippers	Global Importance(%)			Local Importance(%)			Historical Importance(%)		
	DC	HC	TC	DC	HC	TC	DC	HC	TC
(1,2)	0,12	29,53	5,71	5,75	3,46	5,17	0,12	17,87	3,49
(1,3)	-4,78	45,00	6,95	-4,78	47,26	7,48	2,84	24,05	7,8
(1,4)	4,08	47,40	17,42	4,08	29,57	11,93	4,08	55,43	19,89
(2,3)	8,12	10,47	8,64	8,12	10,47	8,64	20,67	11,25	18,58
(2,4)	5,68	1,50	4,35	5,68	1,64	4,39	12,75	-6,06	6,75
(3,4)	24,18	8,12	17,99	24,18	15,44	20,81	24,18	35,71	28,63
Average	6,23	23,67	10,18	7,14	17,97	9,74	10,77	23,04	14,20
(1,2,3)	-2,94	50,22	8,38	1,86	32,70	8,43	15,70	-10,42	10,14
(1,3,4)	45,55	19,14	38,80	45,55	27,21	40,86	45,55	35,02	42,86
(2,3,4)	26,13	6,51	19,80	26,13	16,04	22,87	26,13	40,00	30,61
Average	22,91	25,29	22,33	24,51	25,32	24,05	29,13	21,53	27,87
(1,2,3,4)	24,48	28,84	25,72	27,68	23,91	26,61	28,39	33,65	29,89
Average	24,48	28,84	25,72	27,68	23,91	26,61	28,39	33,65	29,89

Table 8: Impact of centralized reputation-based WDP computation on transportation costs

when collaborating they have adjust their valuations to the worst and that in the decentralized approach shippers overestimated the the service quality of the carriers.

Looking to the total costs, there is always a gain by collaborating. savings (in average) in direct costs, hidden costs and total costs increase by increasing the number of collaborators (the saving of the collaboration of the 4 shippers is better than the average of savings of the collaboration of 3 shippers, which is also better than the average of saving of the collaboration of 2 shippers). Results show that, with instances of four shippers, they may save 27.4% of their total costs (average of the three strategies) if they participate in a centralized market instead of a decentralized market.

## 6 CONCLUSION

This paper proposed a centralized procurement auction in which a set of shippers collaborate by participating together in the same combinatorial auction. We address the WDP knowing that: (1) a same bid may include shipping contracts requested by different shippers and (2) a carrier's reputation may differ from one shipper to another. Three ways for weighting shippers valuations of carriers reputation are proposed: global importance, local importance, and historical importance. Preliminary results show that centralized markets outperform decentralized markets, in both cases when considering carriers reputation (with instances of four shippers they save 27.4% of their costs) , or not (with instances of four shippers they save 9.37% of their costs). Also, savings in costs increase by increasing the number of collaborators in the centralized combinatorial transportation auction.

Although shippers in a centralized market altogether pay less than the sum of their costs if they run an auction for each one (decentralized market), there is

any warranty that each shipper participating in the centralized market will pay less than if he participate in a decentralized market (run alone his auction). As future work, we aim to decide from the three proposed approaches, which one is the better. To this end, the CAP of each approach will be solved and the result is the cost to be allocated to each shipper participating in the centralized market according to each approach. The retained approach should ensure the maximum of equitability between shippers. Finally, we only considered the reputation-based centralized market of TL transportation procurement. The case of reputation-based two-sided auctions in which several shippers and carriers participate by submitting bids has to be studied.

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