

# A Reputation Based Electronic Government Procurement Model

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## ABSTRACT

E-procurement systems allow governments to efficiently manage their contracts by improving interactions with suppliers, and by increasing transparency. Governments generally choose their suppliers based on the minimum price. However, other criteria than price may be considered to help governments choose the best suppliers. This paper proposes a formal reputation model that is intended to determine the winners of an e-procurement process. The proposed model combines three elements: (1) the direct reputation of the supplier, (2) the indirect reputation of the supplier, and (3) the difference in beliefs between the government and the supplier. Using a multi-agent approach, the proposed model compares between situations where reputation is integrated along price for selecting suppliers and when it is not. Results show that the proposed reputation model may lead to lower costs.

## Keywords

*Negotiation; e-procurement; e-government; Reputation; Combinatorial Auction; Truckload; Winner Determination Problems.*

## 1. INTRODUCTION

E-government aims at making the interaction between government and citizens (G2C), government and businesses (G2B), and inter-agency relationships (G2G) more cooperative, convenient, and transparent [22][25][38]. It allows a better delivery of services to citizens, improved interactions with businesses and industries, a less corruption within governmental agencies, an increased transparency, greater convenience, a higher revenue growth, and finally a cost reduction [1][18][26][37].

Electronic procurement (e-procurement) facilitates the acquisition of commodities through the Internet [15][27][35]. It helps automating all major steps of the purchasing process such as product requirements definition, search and selection for suppliers, negotiation, and contracting with suppliers [43]. E-procurement technologies reduce administrative costs, order fulfillment cycle time, inventory levels, and prices paid for goods [11] [52]. It also affords better conditions for industrial institutions to collaborate with each other [7][13][20][55].

This paper focuses on G2B and specifically on the externalization of services and Electronic Government Procurement (eGP). eGP systems [18][22] are known to increase transparency, and productivity of day-to-day procurement activities within agencies to

make suppliers more willing to do business with the government [13][42].

Even electronic platforms have in general improved government activities, current used strategies rarely led to optimal solutions in supplier selection procedures. For example, in some countries, governmental agencies determine the winning firms based on the lowest bidder price. Concrete examples substantiate that this selection criterion is not effective as, in practice, it rarely led to the lowest costs solutions [2]. Hence, other criteria should be integrated when it comes to select firms.

Normally, an applicant agrees to deal with a firm only when mutual trust exists [5][58]. The trust degree between the government and firms represents one of the criteria that should be considered in the selection process. When trust is highly considered in a negotiation process, unnecessary interactions with unreliable firms are eliminated and negotiation outputs are improved [46][59]. Accordingly, the objective of this paper is to propose a formal reputation model that is intended to determine the winners of an e-procurement process. The proposed model combines three elements: (1) the direct reputation of the firm, (2) the indirect reputation of the firm, and (3) the difference in beliefs between the applicant (government) and the firm. These three elements are computed based on five parameters: (1) the negotiation field, (2) the arrangement weight, (3) the arrangement time, (4) the reliability degree, and (5) the importance degree of the firm. The proposed model is applied in the case of an auction for the procurement of transport services that engages a governmental agency with a set of carriers.

The paper is organized as follows. Section 2 presents a literature review on the e-procurement technology. Section 3 identifies the three elements and the five parameters used to build our reputation model. Section 4 describes the proposed formal reputation model. Section 5 presents the experimental results. Section 6 represents a discussion about the possibility of the integration of reputation systems in the e-government procurement model and we conclude in Section 7.

## 2. E-PROCUREMENT : LITERATURE REVIEW

Procurement is an integral part of B2B processes [42][51] and a procedure that allows organizations to operate efficiently. In a procurement process, the applicant sends an invitation to tender to different firms and waits for their replies. When he receives the responses, a negotiation process is started with the interested firms. Through procurement, an applicant aims to find a good combination of firms for the acquisition of commodities while the

objective of the firms is to win the invitation to tender with maximum profits [13][20]. Within the fast growing of B2B market, online procurement (“e-procurement”) has become a subject of discussions in both the private and the public sectors and it has been viewed as an opportunity for efficiency gains in the public sector [17][20][55]. E-procurement is the value-added application of Internet solutions to facilitate, integrate and streamline the entire procurement process from applicant to firms and back [35][51]. In the literature, the e-procurement system is defined as a user-friendly, Internet-based purchasing system. It offers electronic purchase order processing and enhanced administrative functions to buyers and suppliers, resulting in operational efficiencies and potential cost savings [17][20][21]. E-procurement processes minimize meaningless information circulation (due to bureaucratic documents exchange), provide clear and discernible job descriptions, and procure goods within defined deadlines. In e-procurement systems, the required time to generate a manual purchase order, to place an order, and to follow up with vendors is substantially reduced to few simple mouse clicks [13][42].

## 2.1 Challenges to e-Procurement

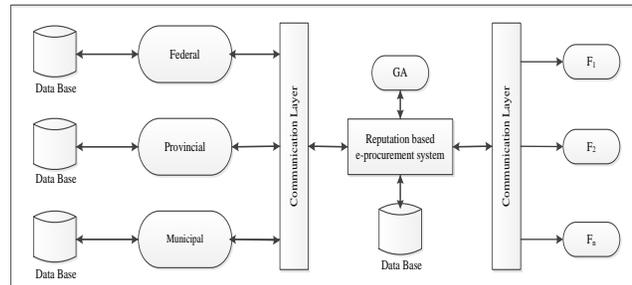
Electronic data interchange (EDI) is widely used by firms in their purchasing processes [11][12]. EDI has led to improvements over the traditional procurement. However, its implementation is known to be expensive and restricted to only biggest firms [12][49][52]. The integration of Internet in e-procurement led recently to important developments and the openness of the technique to a largest set of firms [11][52]. Many scholars have demonstrated the impacts of the use of the e-procurement technology [7][17][55]. E-procurement has turned the formerly traditional purchasing function into a competitive weapon [13][21][51][53]. Companies have invested large amounts of money in e-procurement to boost their efficiency [20]. The longer term cost reduction enables companies focus their resources on more strategic initiatives [17][20] [42].

E-procurement systems bring different advantages to firms. It first allows firms to reduce costs by eliminating paperwork, rework and errors [20][21]. Second, it ensures a continuous and full reporting of requisitions, items purchased, orders processed, and payments made through a centralized tracking of transactions [35] [54]. Third, it helps organizations by ensuring that the correct level of authorization is applied to each transaction by the use of standardized approval processes and formal workflows. Finally, it improves the productivity since internal customers can obtain the items they want from a catalogue of approved items through an on-line requisition and ordering system. Hence, procurement staff can be released from processing orders and handling low value transactions to concentrate on strategic sourcing and improving supplier relationships [7][17].

## 2.2 Reputation based e-Procurement system Architecture

A firm can apply for any procurement that can take place at any government level (i.e. Federal, Provincial, or Municipal). A firm can sometimes win a procurement and sometimes lose it. In addition, a firm can provide the needed results of a procurement and sometimes it fails to do it or even incur to additional costs that were not expected. Saying that, the government agencies, at different levels from federal to municipal, face the problem of determining the winning firms of their procurements. However, in different legislation, the firm who answers the request for proposal and that offer the lowest price will win the procurement. These

government agencies do not generally talk to each other about the bidding firms and generally do not take into account other government agencies opinions about these firms, even if these opinions may change the result of a procurement if considered. This paper demonstrates that other criteria than price can be considered when determining winner firms. Hence, it becomes important to test the opportunity that these agencies share their opinions with regard to the firms in order to improve the selection processes of procurement winners. This opinion is referred to as the reputation of the firm. Thus, in this paper, the government agency (GA) considers the firms reputation as another criterion in the selection process to determine winning firms.



GA: government agency (federal, provincial, or municipal)

F: Firm

**Figure 1: General Architecture of the reputation e-procurement system**

Figure 1 shows the general architecture that can be implemented to build an e-procurement system based on the firms reputation. Each component has a function explained as follows:

**Government Agency (GA):** The GA sends an invitation to tender to different firms and wait for replies from those who are interested in. The objective of the GA is to find a good combination of firms for the delivery of its products while minimizing its transportation cost.

**Firms (F):** Several firms are invited to participate in the government procurement. For this, they submit their bids to the GA through the communication layer.

**Federal/Provincial/Municipal agency:** Based on their historic data, the government agencies send their recommendations with regard to the firms to the GA.

**Reputation based e-procurement system:** The reputation based e-procurement system is the mechanism for determining the winning firms. The selection process is based on the price and the reputation of the firms. The reputation is computed based on the historic data of the GA, the recommendations sent by the government agencies, and the bids of the firms.

In this paper, we build a multi-agent based simulation model, to test the reputation of firms, and compare situations when winning firms are determined based only on the price and when winners are determined based on both price and reputation. We integrate, using a multi-agent approach, the reputation of a firm as part of the hidden costs induced by a deal and hence a salient criterion, along price, for firms selection.

## 3. REPUTATION IN MULTIAGENT SYSTEMS

Many research works proposed multi-agent models based on reputation [5][29][30][36][40][47]. Reputation is computed based on three elements: the difference in beliefs, the direct historical interaction between the two agents, and the indirect reputation [10].

The *difference in beliefs* allows a government agent to check the accuracy of the data received from a target firm agent [10]. For example, a firm agent  $a_j$  proposes the price of 300 dollars for a delivery of a service. A government agent can believe that the price of such service should not exceed 100 dollars and may conclude that the agent  $a_j$  is not honest.

The *direct reputation* between both agents (government and firm) is relative to the past arrangements concluded between the two agents [19][58]. If the number of satisfied arrangements is greater than the unsatisfied ones, the government agent may conclude that the target firm agent is credible and should have a good direct reputation [46][56][59].

The *indirect reputation* represents the reputation of the target firm agent with regard to other government agents [48][56]. The indirect reputation helps a government agent to have a better idea of the target agent [3][19] through the recommendations of other government agents [30][32][58]. These recommendations define an expected behavior of the contracted on the bases of observations and information of witness agents (other government agencies) in a specific context and at a given time [33][56].

In what follows, we determine the five parameters that have to be considered when computing the three elements of reputation (the direct reputation of the firm, the indirect reputation of the firm, and the difference in beliefs between the applicant (government) and the firm: 1) negotiation field [9][14][19][23][58], 2) weight of arrangement [29][43], 3) time of arrangement [19][29], 4) reliability degree [4][58], and 5) importance degree [4][47][58].

First, the *field of a negotiation* refers to the importance of the negotiation terms [9][14]. A negotiation on a contract of one million dollars is more important than a negotiation on a contract of a thousand of dollars [19][23] [29].

Second, the direct reputation between two agents is computed from their past arrangements. For each negotiation field, government agents have to weigh the past arrangements with regard to the *time* when they occurred; recent arrangements have more weight than past ones [29][43]. Similarly, when two arrangements are made in the same period of time, the government agent should give more *weight* for the arrangement which has obtained more profits [39].

Third, for both direct and indirect reputation, a minimum number of past arrangements (received recommendations) have to be considered when computing the reputation of target firm agents [45] [58]. Accordingly, to have a good assessment of direct and indirect reputation, each evaluating agent should have a minimal number of arrangements (received recommendations) with the target agent [4] [45][59]. This minimal number is referred to as the *reliability degree* [4].

The last parameter refers to the *importance degree* that other governments 'agent (witness agent) have with regard to the target firm agent [8][19]. The *importance degree* gives information about the arrangement rate between the witness agent and the target firm [29]. Hence, the government agent collects the importance degree of witness agents when it relies on other government agents' recommendations with regard to a firm. This parameter is used to differentiate between the various received recommendations [4].

The main contribution of this paper is to combine the quoted elements in order to set a global reputation model aiming at enhancing e-government procurement on the basis of reputation. First, we provide new formulas to compute the difference in beliefs and the weight of arrangement. Second, we improve the formulas

proposed respectively in the literature for the calculation of the direct and indirect reputation, and the time of arrangement in order to simulate a more realistic environment. Finally, we introduce the negotiation field as a new parameter to be considered in computing the firm reputation.

## 4. THE REPUTATION MODEL

Let  $A$  be the set of firm agents where  $A = \{a_1, a_2, \dots, a_n\}$ . Let  $Ap$  be the notice of tender submitted by the government agent.  $Ap$  is a set of  $p$  criteria  $c_i \{c_1, c_2, c_3, \dots, c_p\}$ . Let  $R_d(a_i)$  be the direct reputation of target firm agent  $a_i$ ,  $R_{ind}(a_i)$  the indirect reputation of target firm agent  $a_i$ , and  $DB(a_i, Ap)$  the difference in beliefs between the firm agent  $a_i$  and the notice of tender  $Ap$ . Let  $Tr(a_i)$  in  $[0,1]$  be the trust degree of the target agent  $a_i$ .  $Tr(a_i)$  is computed as the sum of  $R_d(a_i)$ ,  $R_{ind}(a_i)$ , minus  $DB(a_i, Ap)$  (equation 1). The minus is explained by the fact that if there is a big difference in beliefs between both agents, the target agent is not considered as credible. In the equation,  $\alpha_1$ ,  $\alpha_2$ , and  $\alpha_3$  represent respectively the weights assigned to direct reputation, indirect reputation, and difference in beliefs. These weights, which are defined by the government agent, represent the importance of each element with  $\sum_{i=1}^3 \alpha_i = 1$ . The importance of each element (its quantitative value) is closely related to the strategy adopted by the government. For example, if the government agent decides to favor suppliers with which it has already done business, it will increase the value of the weight assigned to the direct reputation ( $\alpha_1$ ). However, if the government agent would like to open the procurement process to new entrants; it will increase the indirect reputation weight ( $\alpha_2$ ) with regard to the direct reputation weight ( $\alpha_1$ ). The value of all the reputation elements is between 0 and 1.

$$Tr(a) = \alpha_1 \cdot R_d(a) + \alpha_2 \cdot R_{ind}(a) - \alpha_3 \cdot DB(a, Ap) \quad (1)$$

### 4.1 Reputation Parameters

Five reputation parameters are identified to compute the three elements of a reputation: the negotiation field, the weight and time of arrangement, the reliability weight of the target agent, the importance degree, and the reliability degree. In what follow, we describe how these parameters are computed.

#### 4.1.1 Negotiation field

The negotiation field represents the influence of a management's domain (domains related to oil, toxic, inflammatory products, food products, etc.) on the conduct of a negotiation process [14][19]. This parameter is important to consider when computing reputation [9][14][19][23]. Not all scholars have integrated the negotiation field in their reputation models [5][8][19][29][30][43][45][58][59]. In the paper, we propose that a government agent, before starting a negotiation, assigns for each field  $D_i$  a negotiation value ranging from 0 to 1. We only introduce this parameter to assess its impact, but we do not provide a formula to compute it. This parameter can be computed with reference to investment, price, necessity, sensitivity, utility, etc [9][14].

#### 4.1.2 Weight of Arrangement

It is noteworthy to mention that, in our knowledge, the weight of an arrangement has not been previously dealt with in the literature [5][8] [19][29][30][43][47]. In this paper, the weight of an arrangement of a firm agent is computed through the historical

deals between the government agent and the firm agent [29][33][43]. The formula integrates performances of the government agent during a certain period of time. For a government agent, a performance can be defined as the economies generated in a given period [39]. Let  $Rd_t$  be the performance of the government agent in the period of time  $t$ . Let  $RAr_{i,t}$  be the performance of the government agent with the firm agent for the period  $t$ . Let  $Pr_{i,t}$  be the rate (see formula 2) of the performance of the firm agent with regard to the whole performance of the government agent at period  $t$ .  $Pr_{i,t}$  is computed as follow:

$$Pr_{i,t} = \frac{RAr_{i,t}}{Rd_t} \quad (2)$$

Let  $S_t$  be the set of the performances rates of all the firm agents with which the government agent has reached an agreement for the period  $t$ . Let  $MPr_t$  be the maximum rate performance of  $S_t$ .  $MPr_t$  is computed as follow:

$$MPr_t = \{Pr_{k,t} \in S_t \mid Pr_{k,t} \geq Pr_{j,t} \text{ et } \forall Pr_{j,t} \in S_t\} \quad (3)$$

We compute the weight of a firm agent with regard to the government agent as the distance between  $Pr_{i,t}$  and  $MPr_t$  (see formula 4). When this distance increases, the arrangement weight decreases and vice-versa. We use the square variance to compute this distance as depicted in [3].

$$P_i = 1 - \frac{|Pr_{i,t}^2 - MPr_t^2|}{MPr_t^2} \quad (4)$$

#### 4.1.3 Time of Arrangement

The number of past arrangements is widely used in the literature on reputation [19][28][36]. We adopt, in our model, the formula of the exponential weighting moving average (EWMA) to calculate the arrangement time parameter. This average uses a weighting of terms which decreases exponentially as it gives more weight to the recent data at the expense of old data [16].

Let  $x_t$  be the value of stored parameter in the government database.  $\bar{x}_t$  is the new value taking into account time influence. A recent value of this parameter has a greater weight than old values of that parameter. Using the EWMA,  $\bar{x}_t$  is computed as follows:

$$\bar{x}_t = \alpha x_t + (1 - \alpha)t x_t \quad (5)$$

With:

$\alpha$  is the smoothing constant that depends on the number  $N$  of time periods set by the government negotiator [30]:

$$\alpha = \frac{2}{N+1} \quad (6)$$

$t$  is the period when the  $x_t$  value is obtained.

The arrangement time ranges from 1 to  $N$ . It is equal to 1 when the value is obtained at the time  $t_0 = 1$  and it is incremented by 1 at each period of time until it reaches the value  $N$  ( $t_N = N$ ).

#### 4.1.4 Importance degree

The formula used in [4] to compute the importance degree is applied. Let  $N_g$  be the number of arrangements between the target firm agent and government agent  $g$ . Let  $TN$  be the total number of arrangements made by agent  $g$  in its entire career. The importance degree  $\theta_g \in [0,1]$  of agent  $g$  is computed as follows:

$$\theta_g = \frac{N_g}{TN} \quad (7)$$

#### 4.1.5 Reliability degree

We use the formula proposed in [45]. Let  $n$  be the number of arrangements (or the number of received recommendations) and  $itm$  the number of acceptable arrangements (or acceptable recommendations) to judge a target firm agent (witness government agent), the reliability degree  $\xi \in [0,1]$  is computed as follows:

$$\xi = \begin{cases} \sin\left(\frac{\pi}{2 \cdot itm} |n|\right) & \text{If } |n| \in [0, itm] \\ 1 & \text{Otherwise} \end{cases} \quad (8)$$

In the next section, we present the formula expressing the direct reputation, the indirect reputation, and the difference in beliefs.

### 4.2 Direct Reputation

Direct reputation is computed from the previous arrangements [40][47]. In [19] and [56], the previous arrangements are classified in two types: the satisfactory arrangements ( $n_s$ ) and the unsatisfactory arrangements ( $n_u$ ). In [32], the direct reputation is computed as a beta expectancy ( $E(x) = \frac{\alpha}{\alpha + \beta}$ ) by replacing  $\alpha = n_s + 1$  and  $\beta = n_u + 1$ . Satisfied and unsatisfied arrangements depend on time as we provide more weight to recent actions, on the importance of arrangement (weight), and on the negotiation domain. Hence, the beta expectancy formula is modified as follows:

$$R_d(a) = \xi \cdot \frac{n'_s + 1}{n'_s + n'_u + 2} \quad (9)$$

With:

$\xi$  : the reliability degree ;

$n'_s$  and  $n'_u$  : the weight of satisfactory arrangements and unsatisfactory arrangements:

$$n'_s = \sum_{i=1}^{n_s} (\bar{n}_{s,i} \times P_i \times D_i) \quad (10)$$

$$n'_u = \sum_{i=1}^{n_u} (\bar{n}_{u,i} \times P_i \times D_i) \quad (11)$$

Where  $\bar{n}_{s,i}$  and  $\bar{n}_{u,i}$  are respectively the numbers of satisfied and unsatisfied arrangements influenced by the time factor,  $P_i$  is the weight of arrangement  $I$ , and  $D_i$  is the influence of negotiation field on the arrangement  $i$ .

### 4.3 Indirect Reputation

The government agent can ask other government agents about the firm agent reputation. Recommendations done by other government agents about the target agent, are called the *indirect reputation*, and are evaluated in two steps. In the first step (the selecting step), the government agent eliminates the non acceptable recommendations by setting an acceptance threshold  $\theta_g$  as [4]:

$$\begin{cases} \text{Accept the recommendation of witness agent } g \text{ if } \theta_g > \text{Value} \\ \text{Refuse the recommendation} & \text{Otherwise} \end{cases} \quad (12)$$

In the second step, the government agent combines all accepted recommendations and computes the indirect reputation  $Cr_{ind}(a)$  of the target firm agent  $a$  as follows:

$$R_{ind}(a) = \xi \cdot \frac{\sum_{g=1}^{Nr} \theta_g \cdot \bar{R}_{a,g}(a)}{\sum_{g=1}^{Nr} \theta_g} \quad (13)$$

In this formula,  $\bar{R}_{a,g}(a)$  is the trust degree of witness agent  $g$  (other government agents) with regard to target agent  $a$ . This degree is influenced by time as recent values are given more importance.  $\theta_g$  represents the importance degree of the target agent  $a$  from the point of view of witness agent  $g$ . Finally,  $\xi$  is the reliability degree.

### 4.4 Difference in Beliefs

The difference in beliefs is assessed by the distance between the observed value (given by the target firm agent) and the estimated value (belief of the government agent) [5]. When this distance increases, the difference in beliefs will increase and vice-versa. The difference in beliefs has not been integrated into any reputation model in literature [5][8][19][29][30][43][47][58][59]. Hence, we introduce a new formula to compute the difference in beliefs based on the square variance [41].

In a multi-attribute negotiation, each bid  $Ap$  is a set of  $p$  criteria. Let  $V_k$  be the value of the criterion  $c_k$  submitted by target agent  $a$  and  $B_k$  the belief of the government agent on this criterion. Any criterion can have either qualitative or quantitative values. Let  $DB(a,k)$  be the difference in beliefs of criterion  $c_k$ . In the case of a quantitative criterion,  $DB(a,k)$  is expressed as follows:

$$DB(a,k) = \frac{|V_k^2 - B_k^2|}{\text{Max}(V_k^2, B_k^2)} \quad (14)$$

In this formula, the maximum between the observed value ( $V_k^2$ ) and the estimated value ( $B_k^2$ ) is required to have a positive normalized difference in beliefs from 0 to 1

In the case of a qualitative criterion,  $DB(a,k)$  is computed as follows:

$$DB(a,k) = |\mu(V_k)^2 - \mu(B_k)^2| \quad (15)$$

When the criterion is qualitative, the calculation of the distance, between the observed value ( $V_k$ ) and the estimated value ( $B_k$ ), cannot be done directly. In this case, a step of defuzzification is needed to transform qualitative values into quantitative ones between 0 and 1 [8]. The defuzzification uses the common

membership function  $\mu(x) \in [0,1]$  set by the government agent at the beginning of the transportation auction.

In a multi-attribute negotiation, each bid  $Ap$  is composed of a set of criteria. The difference in beliefs with the target firm agent  $a$  for bid  $Ap$  is:

$$DB(a, Ap) = \sum_{k=1}^p w_k \cdot DB(a, k) \quad (16)$$

With  $w_k$  is the weight of the criterion  $k$ . These weights are determined by the negotiator with  $\sum_{k=1}^p w_k = 1$

Based on the direct reputation, indirect reputation, and difference in beliefs, the formula to compute the degree of trust that should be associated to a target firm agent is presented as:

$$Tr(a) = \alpha_1 \cdot \xi \cdot \frac{n'_s + 1}{n'_s + n'_t + 2} + \alpha_2 \cdot \xi \cdot \frac{\sum_{g=1}^{Nr} \theta_g \cdot \bar{R}_{a,g}(a)}{\sum_{g=1}^{Nr} \theta_g} - \alpha_3 \cdot \sum_{k=1}^p w_k \cdot DB(a, k) \quad (17)$$

## 5. THE EXPERIMENTAL RESULTS

In this paper, we consider the procurement of a transportation of goods belonging to a government agency. The objective of the agency is to determine the winning firms that will ensure the minimum cost taking into account their reputation. This type of problems is called the Winner Determination Problem (WDP).

The agency sends its transportation requests to the market. A request is a contract of carriage in which the agency specifies the origin and delivery points, delivery frequency (daily, weekly, monthly), etc. [6][44]. The set of all contracts, sent by the agency, is identified by  $K$ . Each firm submits a set of bids to respond to the agency's request. A bid  $b$  is defined by a couple  $(K_b, BP_b)$ , where  $K_b$  is the set of contracts that the firm bids on in his bid  $b$  and  $BP_b$  is the price asked by the firm to serve all the contracts in  $K_b$ . Formally, the problem is expressed as follows:

$$\sum_{b \in B} \delta_{bk} x_b \geq 1 \quad \forall k \in K \quad (18)$$

$$x_b \in \{0,1\} \quad \forall b \in B \quad (19)$$

Where  $B$  is the set of all received bids, and  $x_b$  is equal to 1 if bid  $b$  wins; 0 otherwise. The constant parameter  $\delta_{bk}$  is defined for each contract  $k \in K_b$  and for each bid  $b \in B$ . This parameter is equal to 1 if the bid  $b$  covers the contract  $k$  and 0 otherwise. Constraints (18) ensure that each transportation contract requested by the agency is served.

To validate our model, two scenarios are submitted for comparison. In the first scenario, we determine the winners of the auction using only the bid prices. In the second, the winners of the auction are identified using the reputation model developed in this paper.

Table 1 defines formally the two WDPs.  $BP_b$  is the basic price of bid  $b$ .  $HC_b$  is the hidden cost of the bid  $b$ . In this case study, three estimated hidden costs are considered: Delay hidden cost, Damage hidden cost, and Cancellation hidden cost. The hidden cost of the bid  $b$  is computed as the sum of the three estimated hidden costs  $HC_k$  for each contract  $k \in K_b$ :  $HC_{kr}$  (Delay hidden cost),  $HC_{kd}$  (Damage hidden cost), and  $HC_{ka}$  (Cancellation hidden cost) (for more details, the reader is referred to [44]).

$$HC_k = HC_{kr} + HC_{kd} + HC_{ka} \quad (20)$$

$$HC_b = \sum_{k \in K_b} HC_k \quad (21)$$

**Table 1. The winner determination problems**

Scenarios	WDPs
<b>Scenario 1:</b> <i>The classic case</i>	$(P1) : \min \sum_{a \in A} \sum_{b \in B(a)} BP_b x_b$
<b>Scenario 2:</b> <i>The integration of hidden costs calculated based on the Trust degree</i>	$(P2) : \min \sum_{a \in A} \sum_{b \in B(a)} ((BP_b + HC_b) (1 - Tr(a))) x_b$

## 5.1 The WDPs setting

The instances with specific characteristics are randomly generated based on a set of parameters such as: the size of the problem (the number of bids, the number of contracts, the number of firms), the contract size (the number of shipments, prices, etc.), and the trust degree of firms (the recommendations number of witness government agents, the number of arrangements, etc.). All of these parameters are generated randomly using the CATS generator through its PATH distribution module developed by [34]. We used the CATS suite as a black box to which we passed as input the number of contracts ( $|K| = 20, 40, \text{ and } 60$ ), a number of firms ( $|A|$ ), the number of firms that is chosen randomly from the interval  $[\frac{|B|}{5}, \frac{|B|}{10}]$ , a number of received bids ( $|B| = 100, 120, \text{ and } 180$ ), a number of received recommendations from witness government ( $|R| = 200, 250, \text{ and } 300$ ), and a number of historical arrangements made with firms ( $|H| = 500, 600, \text{ and } 700$ ). Participating firms will be distributed randomly on the contracts, bids, recommendations, and historical records. All the parameters, used to calculate the Trust degree of each firm  $a \in A$ , were randomly generated for each combinatorial auction ( $|B|, |K|, |A|, |R|, |H|$ ). For each auction of six contexts, we generate 100 instances for a total of 600 instances.

## 5.2 Generated Results

The resolution of the two WDPs is implemented in C++. We used the ‘‘Branch-and-Bound’’ algorithm of CPLEX 12.1 32-bit (with default parameters) to solve the various randomly generated instances. The tests were performed on a machine with Intel Core 2 Duo 3.00 GHz and 4.00 GB RAM.

Table 2 summarizes the results obtained from the generated instances. For each scenario, we present a series of averages with regard to the winning firms of 100 instances. These averages are computed for the base price, the estimated hidden costs of cancellation, the estimated hidden costs of damage, the estimated hidden costs of delay and the total costs (the sum of the base price and the three estimated hidden costs).

From Table 2, the first scenario generates the lower basic prices, in the six contexts, compared to the second scenario. This result is expected since the first scenario selects firms only by minimizing the basic price.

However, when we consider the transport hidden costs, only 33% of all instances generated by the first scenario had the minimum total cost of transport. Thus, we conclude that the basic price

cannot be the only criterion to be considered in the determination of the winning firms.

**Table 2. Summary of experimental results for Scenarios 1 and 2**

Context ( $ K ,  B ,  A ,  R ,  H $ )	Sc	Average of results				
		Basic price	Cancel Hidden Cost	Damage Hidden Cost	Delay Hidden Cost	Total
1 (20,100,10,10,20 0,500)	1	93508	-127708	210475	25121	201396
	2	95686	-131616	217085	25871	207026
2 (20,100,20,20,20 0,500)	1	94087	-121134	201181	24257	198391
	2	96771	-125781	200918	25007	196915
3 (40,120,12,25 0,600)	1	121596	-148555	255619	29989	258649
	2	124449	-155491	259810	31575	260343
4 (40,120,24,25 0,600)	1	121053	-141004	249411	28671	258131
	2	123507	-160897	245647	28656	236913
5 (60,180,18,30 0,700)	1	144269	-191156	328132	39595	320840
	2	147434	-212297	319131	39540	293808
6 (60,180,36,30 0,700)	1	143340	-180737	299103	35694	297400
	2	147370	-187714	298895	36955	295506

Table 2 shows that for scenario 1, the basic price represents on average 46% of the total cost that could be incurred by government during operations. For scenario 2, the basic price represents 51% of this total cost. On the other hand, hidden costs represent on average 54% of the total cost for scenario 1 compared to 49% for scenario 2. Hence, as expected, scenario 2 yields an increase in the total direct cost paid to firms versus a decrease in the total hidden cost. Thus, although the government is paying more in the direct cost, a significant saving of total transport costs can be achieved when the reputation of the firm is modeled. This allows us to conclude that when the government considers more historical data in its selection process, it has more chances to work with the good target firm.

**Table 3. Economic gain of Scenario 2 versus Scenario 1**

Context ( $ K ,  B ,  A ,  R ,  H $ )	Average saving				
	Basic price	Cancel Hidden Cost	Damage Hidden Cost	Delay Hidden Cost	Total
1 (20,100,10,10,20 0,500)	2,28%	2,97%	3,04%	2,90%	2,72%
2 (20,100,20,20,20 0,500)	2,77%	3,69%	-0,13%	3,00%	-0,75%
3 (40,120,12,25 0,600)	2,29%	4,46%	1,61%	5,02%	0,65%
4 (40,120,24,25 0,600)	1,99%	12,36%	-1,53%	-0,05%	-8,96%
5 (60,180,18,30 0,700)	2,15%	9,96%	-2,82%	-0,14%	-9,20%
6 (60,180,36,30 0,700)	2,73%	3,72%	-0,07%	3,41%	-0,64%

In order to point out the impact of considering firms reputation on costs variation, we report in Table 3: (1) the average additional or saving direct cost (in percentage) yielded by scenario 2 compared to scenario 1 for each auction context, (2) the corresponding average saving (in percentage) in cancel hidden costs, (3) the corresponding average saving (in percentage) in Damage hidden costs, (4) the corresponding average saving (in percentage) in Delay hidden costs, and (5) the corresponding average saving (in percentage) in total costs. These averages are computed over the

100 instances generated for each auction context. For example, for auction context (60,180,18,300,700), the increase in direct costs lies with an average of 2.15% for all the 100 instances. For the same context, the average savings in total costs reaches 9,20%. The results of Table 3 show that considering firms trust degree in the WDP may lead to important savings in the total transportation cost that is likely to be incurred by government during operations when compared to the case where only ask-prices is considered. The government should take into consideration direct and indirect types of data in his resolution strategy. The mixture of these data provides a more exhaustive analysis which ensures an economic saving in the transportation total cost and also a good service quality.

## 6. DISCUSSION

This paper proposed a theoretical model to consider the concept of reputation to determine the winner of a public procurement. This reputation is based on the direct reputation, the indirect reputation, and the difference in beliefs. This model is facing different challenges that have to be addressed if such solution has to be implemented.

This reputation system that represents a new technology introduced has to be integrated with current e-procurement systems that governments are using today. Hence, it is very important to figure out how these reputations systems can be technologically integrated with the existing e-procurement systems. Thus, it is interesting to analyze the relationship between the integration of reputation systems and models of e-procurement system adoption proposed in the literature.

The success of an e-procurement system requires efficient processes at both the internal workflow and the supplier–purchaser relationship [50][52]. At the other hand, e-procurement encounters various uncertainties from internal and external environments [24][35]. In the literature, three factors should be considered in order to make successful the transition from the traditional procurement to e-procurement [11][51][54]. Figure 2 illustrates the three factors which are: 1) the technological factor, 2) the organizational factor, and 3) the environmental factor [12][31][53].

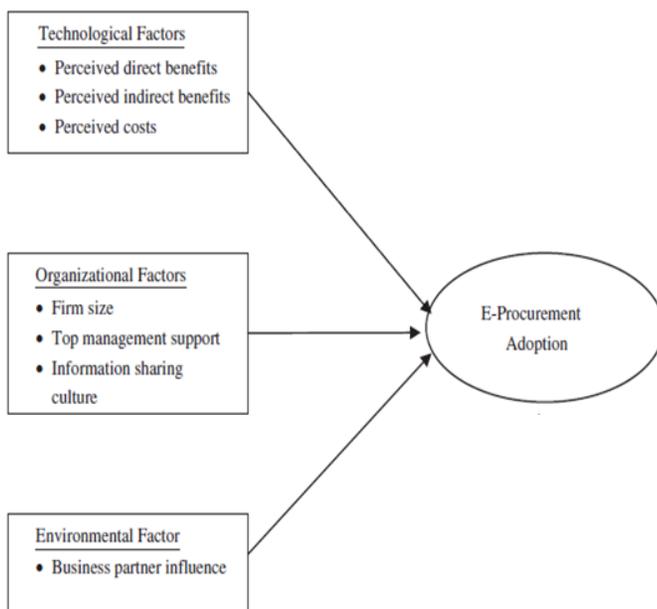


Figure 2: Factors of e-procurement adoption [52]

First, the technological factor refers to the technologies that are in and outside the firm. [13][31]. These technologies are needed to create the standard procurement documentation such as electronic requests for information (e-RFI), requests for proposal (e-RFP) and requests for quotation (e-RFQ) which are used to source goods, and make the framework agreements [11][52]. The reputation systems are involved in the technological factor of government agency. Indeed, the obtained results in this paper shows that the integration of reputation in the e-government procurement represents a source of direct benefits and a source of costs reduction for the government agency.

Second, the organizational factor is related to the firm's managerial structure (centralization, decentralization, formalization, and complexity), and its ability to integrate technological innovation (firm size and scope, informal electronic linkage and communication, information sharing, etc.) [50][51][54]. Thus, the adoption of reputation in e-procurement system requires that each government agency has to maintain a historical database with all the contracts that were provided to firms in each domain of activity. In addition, each agency has to identify the parameters that it judges important to compute the reputation of a target firm.

Third, the environmental factor is refers to the business environment in which government agencies are operating. It is very important to government agencies to share their experiences with regard to their business environment [12][24]. Consequently, government agencies have to exchange information about their suppliers. However, this situation becomes more complicated if the government agencies are not at the same level: Federal, provincial, or municipal; their procurement systems do not necessarily use the same technology or communicate with each other. In addition, each government agency may determine its own parameters to compute the reputation of a firm. When this agency asks other agencies for their reputations about this firm, it would prefer that the other agencies evaluate this firm by using its parameters. However, it is not always true that all agencies are storing the historical data based of the same parameters since its agency may define its proper parameters. Consequently, in a governmental context, it becomes very important to identify the different parameters that may be used by the agencies and store the data related to these parameters.

Jointly, the three quoted factors influence organizational decisions regarding the implementation or not of an reputation e-procurement technology in the government agencies [49][53].

## 7. CONCLUSION

This paper focused on the e-government procurement eGP in the case of transport services between a government agency and a set of firms. We proposed a novel generalized model for the WDP to manage the trade-off between transport prices and firms reputation. This model provides the basic tools for government in order to evaluate the bids they receive from firms and guarantee that they are operating with the firms having the best trust degree. The reputation model is computed based on three elements (direct reputation, indirect reputation, and difference in beliefs) and five parameters (negotiation filed, arrangement time, arrangement weight, importance degree, and reliability degree). The objective is to minimize the total cost that the government could pay in practice in case of problems occurring during the externalization of transport operations that may induce hidden costs.

As future work, there are several issues that need to be studied. First, only three parameters (cancel, damage, and delay) were considered to evaluate the reputation of a firm. However, reliability, travel time, congested time, frequency of service, and

quality of drivers are examples of other parameters that are important in some contexts to measure firms reputation.

Second, it is also noteworthy that the set of competing firms may include new ones with which the government has no past experiences. The government has to find other ways, out of the past experiences, to deal with the cold-start issue and compute the reputation of new firms. In this case, and depending on its risk aversion behavior, the government may adopt different strategies to compute the non-incumbent firms' reputation. For example, a risk-averse government would considerably limit the number of contracts won by a new firm. It would also consider a new firm as having the worst reputation with respect to incumbent firms. Instead, a risk-taker government would consider new firms as excellent ones and assign them the best reputation with respect to incumbent firms. Finally, the government may use the mean, the median or the 75th percentile measures to compute new firms reputation [44].

Third, in order to efficiently implement this solution, legislative concerns have to be considered. In fact, governments have to change their rules when deciding on the winning suppliers. These new rules have to comply with the laws in practice. Consequently, laws have to be changed to allow governments adopt these new strategies to select their suppliers.

Finally, we only considered unilateral auctions in which firms bid on contracts requested by a single government agency. The case of multi-lateral auctions in which several government agencies and firms are involved has to be studied. The challenge in this type of auctions is that a combinatorial bid may include contracts requested by different government agencies who differently evaluate the firms reputation. Government agencies may make economies by collaborating together.

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