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Design of a Web-based Tendering System for e-Government Procurement

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ABSTRACT

Procurement for e-Government is an important part of activities which are similar to the nature of B2B. That is usually characterized by bulk volumes with complex variables, bureaucratic workflows and the need to function in a regulated environment under which many partners participated. In the past, e-Government procurement involved a lot of manual processes which are known to be time-consuming and may be error-prone. In this paper, we present the design of a Web-based Tendering System which aims at improving the efficiency as well as transparency. In addition to a prototype which we developed for proof-of-concept, we modeled the new system in contrast of traditional manual workflow by using a Business Process Re-engineering tool. We showed that certain processes could be automated by leveraging the power of Internet and information technology, as well as operating costs could be lowered in the new model. Various tendering schemes can be supported. In particular, our new design incorporates a decision-support design at the backend for assisting a panel of judges pertaining to suggesting how the jobs should be allocated to different bidders. As a core of the decision-support module, the system has an automated analyzer that rationally considers the bidders' backgrounds and feasibilities, in the perspective of achieving an overall goal.

Keywords

Tendering, e-Government, Procurement, BPR

1. INTRODUCTION

e-Government uses improved Internet-based technology to make it easy for citizens and businesses to interact with the government, streamline processes, and improve citizen-to-government communications. The goal of these initiatives will be to eliminate redundant systems and significantly enhance the government's quality of customer service for citizens and businesses. One of the

application domains of e-Government initiatives would be on G2B where government departments procure goods or services from supplier via open tendering or other means.

e-Tendering in a general sense fits under such a plan of e-Government initiative that add values to trading parties by using Internet technology by facilitating their procurement process for both procurer and supplier. The goal is to improve the productivity and effectiveness for various business processes is in facilitating the trading amongst business partners and the government agencies.

By the authors' observation, e-Tendering service has evolved progressively over the years from online information browsing to integrated business solution. They can be approximately classified into the following four groups which are also seen as a roadmap of evolution.

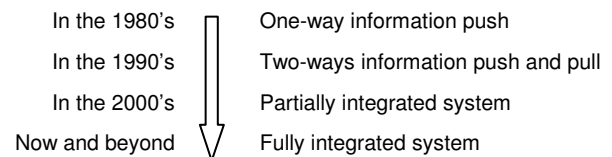


Figure 1. Changes of e-Tendering website over the years.

In principle, e-Tendering systems are about using technology to its fullest to provide services and information that is centered on facilitating information search, tender creating, tendering process, bids evaluation and selection etc.

In the early 1980's, the efforts were pioneered in digitizing the tender information and displaying them on a website as a bulletin board, usually in forms of notices. The e-Government website (of which the Tendering Notice) served as an alternative platform for information display in addition to the traditional method of publishing in Gazettes. Interested suppliers from the public who want to participate in the tendering would have to follow up via human contacts such as phone calls and in-person interviews. All subsequent processes were to be carried out manually and paper-based to close the loop. In the latter years, the usage of the website was extended to allowing files that were digitized from paper documents to be downloaded and online forms can be filled in and submitted online. Some enabled users to pay for the application fees online too, with transactional payment abilities.

Figure 2a shows a scenario where the so-called Web-based Tendering System (WTS) or e-Tendering was mainly used for information display on a website. While most of the frontend

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services that interact with the users (suppliers) are digitized, a large part of the backend processes still remained unchanged. It is known that reforming processes and workflows especially in bureaucratic environment like government bodies involves many policy issues and would have to gradually take time. The backend processes are core-functions of e-Tendering that includes but not limited to the following [1] (c.f. Table 1: The Roles and Activities of Tendering Process in [1]): tender creation, bids evaluation, policy making, decision making and other supports.

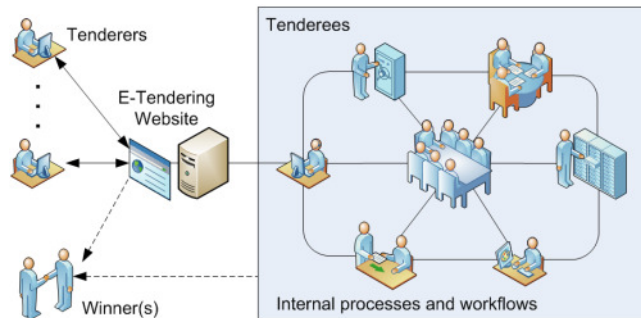


Figure 2a. e-Tendering system with mainly offline processes.

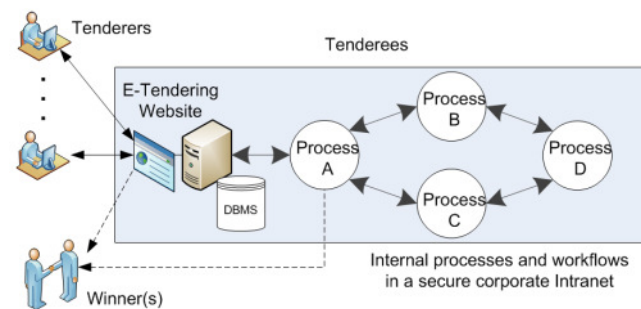


Figure 2b. e-Tendering system unified with online processes.

e-Government efforts progressed eventually into digitizing both the information and services of both frontend and backend. At the turn of millennium, the backend processes were partially integrated with automated workflows. They are more or less digitized and operating in a secure Intranet environment mainly for exchanging and archiving documents. This describes WTS in most e-Government situations nowadays – the frontend is largely used for interacting with users and the backend is partially automated and integrated. The scenario of today's WTS is reflected in Figure 2b and may be a hybrid of Figures 2a and 2b. Figure 2b shows an ultimate scenario which may be the final goal of e-Government reform that the processes are fully integrated and automated. The whole WTS is unified by closely coupling the website and the backend workflow as a whole application.

As a main contribution of this paper, we proposed a design of WTS that can help substantially on migrating some manual processes in the backend to web-based internal process by automating the bid evaluation, decision support for selecting the winner(s) and others. The architecture of the WTS design is modular, hence it is possible to incorporate additional backend processes that eventually leads to a fully unified integration.

The design could be adopted by e-Government as in now when the internal processes are still mostly manual, and under planned to upgrade to a fully connected workflow with even collaborative business and e-Procurement in the future. The paper is structured in the following sections: Section 2 is related works that pinpoint about technological advancements for e-Tendering are in fact readily available, what lacks of now probably is a blueprint to fit them together in line with e-Government developments. Hence this is the motivation for this paper. Section 3 describes on the System Design. Section 4 probes into the details of the decision support module – Bid Evaluation. Section 5 is on the performance modeling by a BPR tool that demonstrates the gains by streamlining certain backend processes. A conclusion is presented in Section 6.

2. RELATED WORKS

This is not meant to be exhaustive but review some important latest publications in literature regarding e-Tendering. As observed by the authors, most of the academic research works concentrated on a particular aspect of e-Tendering, especially on evaluation of tenders by decision support makers. We however advocate that e-Tendering is not merely a website of interactive services dealing with tenderers or analyzing their bids; but rather it is a full set of processes and workflows of evaluation, approval and management issues that span across multiple intra-organization departments and even link up with supply chains.

Architecture – Focusing on the bidding/tendering process, [2] reviewed a list of existing information systems over the Internet that supports this process. They developed a SupplyPoint system, which can electronically support and automate the whole tendering/bidding process of virtual consortia for construction industry. Another similar system is e-Tendering with Web Services by [3]. The system provides the tender document details for the tenderers, and the tenderers submit their tender price via Web services. The paper has a case study on building construction. PreQTender, by [4] is another Web-based tender management system for selecting prequalified tenderers in construction projects. The system aims to increase the integrity and transparency of the prequalification tendering processes.

Most of the papers focus on the tendering mechanisms and the pricing factors, where details on decision-support systems, approval workflow, and bid evaluation as an integral solution are inadequate. They were designed for specific industry sectors.

To respond to this, [5] proposed an application of the Domain Engineering approach for the development of tendering e-marketplace applications. This approach combines the analysis of the e-marketplace domain with a set of Domain Engineering models to support the development of tendering e-marketplace assets. It commented that however, most work on e-marketplaces has concentrated on solving specific problems, rather than providing reusable software development models. This inspired us to opt for a generic, reusable and modular e-Tendering design.

Integration and interoperability issues: They are important especially in our case of e-Government because potentially there would be a large variety of business partners and agencies to relate to in the e-Tendering process. In [6] a web service SOAP messaging architecture is proposed for this purpose. It uses SOAP messages exchange in XML format to improve inefficient manual

or semi-automated tendering process. The inter-processes communications in e-Tendering is modeled in [7].

Decision-support systems: It is an important element usually located in the backend process of a WTS that helps the tenderer to decide which tenderers should be chosen as winner(s) of the contracts. Some popular models studied in the literature are Multi Criteria Decision Making (MCDM) [8][9], Combine Scoreboard Evaluation in tender evaluation [10], Fuzzy set for setting price bid [11] and Genetic Algorithm that used to find tenders that optimize costs [12]. In particular, MCDM is used by integrating the existing statistical models with weight, and Guided Analytic Hierarchy Process (GAHP) [8]. Although a lot of research works are on selecting winners by various methods, few studied about in case of multiple candidates are equally competitive how the jobs could be distributed to them at the best of the tenderer's interest. This motivated us to design a decision-support system to cater for this.

Security: As important support services that ensure an e-Tendering system functions in a secure environment, a number of security techniques including protecting the communications are proposed in [13]. The research in security is a major step required to integrate critical legal requirements into e-tendering system design.

Automated negotiation for B2B: e-Tendering usually provides a bidding platform for parties to compete for a tender. After which negotiation would follow up manually between the winner bidders and the tenderer. Recent research [14] proposed a way to automate the negotiation heuristically as a contribution to a full set of processes integration.

We argue that in the context of e-Government, concerns over changing the internal processes and policies do exist albeit the technology is readily available. In the following sections we present a modular system architecture of e-Tendering that features a decision-support module for tender evaluations, and consequently we show that the system could fit into a scenario where processes can be automated. This is verified by using a BPR tool by Holosofx Inc [15].

In the industry, there are some mature online tendering systems such as Merx in Canada (www.merx.com) and later PhilGEPS in Philippines (www.philgeps.net). Our WTS design can potentially be adopted by them or similar, for evolving to a unified system that extends from information access basis and orders management to a fully integrated tendering workflow, linking the frontend features to the backend processes.

3. SYSTEM DESIGN

In our proposed design, we modeled the roles of users in e-Tendering into individual modules. The idea is that the functions that belong to each user role are encapsulated on their own, making the design flexible to be integrate with existing inter-department workflows. There are several main modules that roughly can be classified as the technical support – database that archive all the information, and web service module that facilities data passing over an Intranet. The other modules go by the typical roles in e-Tendering such as tenderers, tenderers, and general users. In particular, the backend processes are modeled in evaluator module and committee module which are meant for

managing the tendering processes after the bids are received. These backend processes in most existing e-Tendering systems are still conducted manually as shown in Figure 2a. In our design, the committee module and the evaluator module are there to either replace or accomplish these manual works that depends on how far the workflows get automated. At present, while the e-Tendering workflow at the backend is still managed by human users, the modules serve as ICT supports to facilitate online interaction / communication in deciding the winners and how jobs should be distributed. In the future, when the workflow that couples the frontend and the backend processes become fully automated, the modules could be extended with software agent technology and trading rules – that would ultimately achieve a scenario shown in Figure 2b.

The system architecture of our proposed WTS is in Figure 3. The fundamental functions of the core modules are discussed below. And the corresponding data flow diagram is shown in Figure 4.

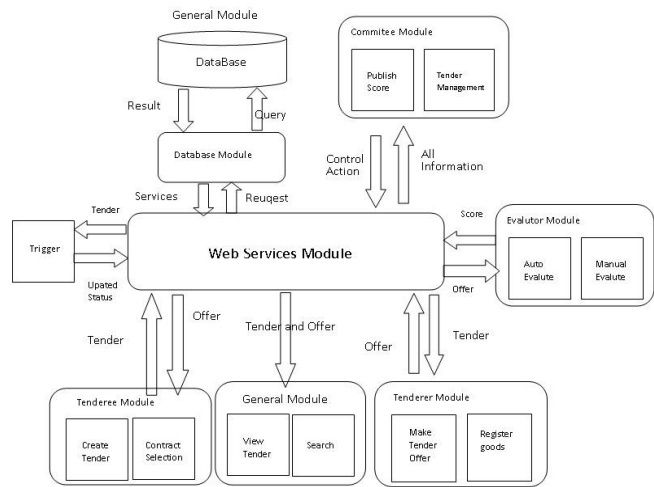


Figure 3. System architecture of the proposed WTS.

3.1 Tenderer

The tenderer module mainly contains two functions: create tender and contract selection. Tenderer should include all the details needed for the suppliers to make tender offers including the addition of criteria into tender at the run time in a flexible way, and allowing the uploading of various kind of contract drawing. Tenders are stored in standardized format in XML for interoperability, which is important for document reuse and sharing among other departments in an e-Government.

Tenderer can create three types of tenders: public, private and re-tendering. While public tender is open for all qualified tenders, private tender is specifically created for certain potential suppliers. Re-tendering is designed for tenderers to re-submit their bids to previously closed tenders in certain kinds of circumstances. In the process of tender creation, a set of criteria is needed to provide the required constraints for the tender attributes. Weight is used to indicate the importance of each criterion, and will be used in calculating a score for a certain tender attribute submitted by the tenderer. Tenderer can choose to use a simpler interface to set the standard criteria usually including price and quantity of the goods; or to add additional criteria whenever necessary.

Tenderee is also responsible for contract selection after the evaluation and the scores of contracts are confirmed by the authorized committee. For a single tender winner intended, tenderee needs to confirm if the winner is the default tender offer with the highest overall score obtained, or another one as desired (which may reflect the unfairness despite the technically produced result). If multiple tender winners are intended, tenderee will need to set up a cut-off score and calculate the unit price for each item requested in the tender. The algorithms for tender allocation among multiple tender winners will be discussed in section 4.

3.2 Tenderer

The tenderer module is for tenderers to make tenders offer and register goods prior to tenders creation. According to the criteria listed in the posted tender, tenderers shall be able to make clear quotations for each goods or service requested by the tenderee.

Besides, a tenderer is encouraged to register the goods or services as the supplies, prior to a tender offer. This provides a consistent specification list of supplies for tenderee in tender creation process. To submit a tender offer, Tenderer retrieves the specific tender and priced items information from the corresponding databases. After the tenderer has made the tender offer, the data will be recorded into the corresponding databases possibly for future use. The idea is to reuse the information that is stored in databases; for ease-of-use and ensuring information accuracy which otherwise may be incurred by human error.

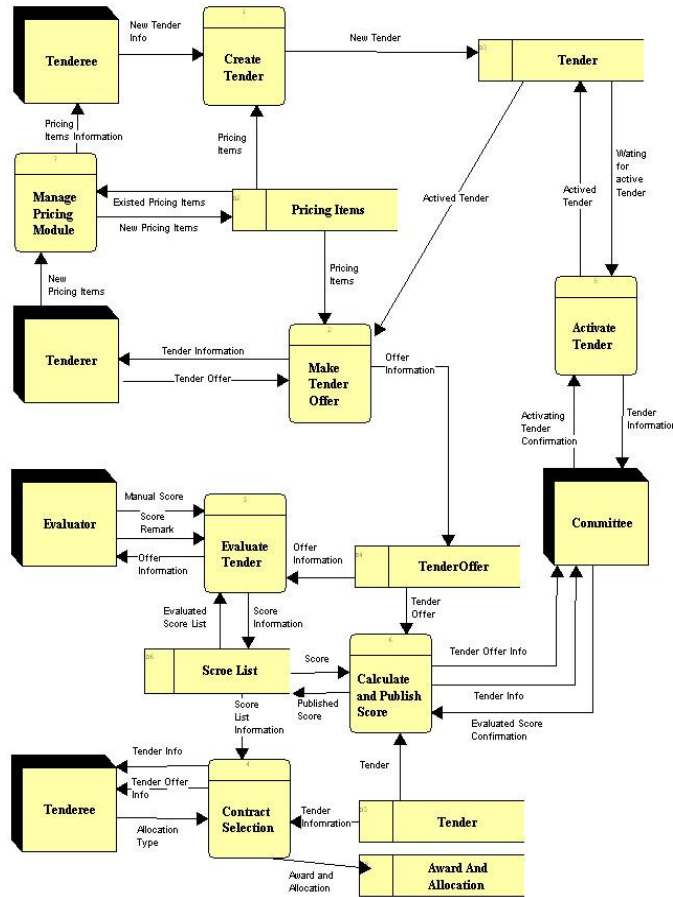


Figure 4. Data flow diagram of WTS.

4. TENDER EVALUATION

The evaluator module is responsible for bid evaluation. Figure 5 shows the evaluation process.

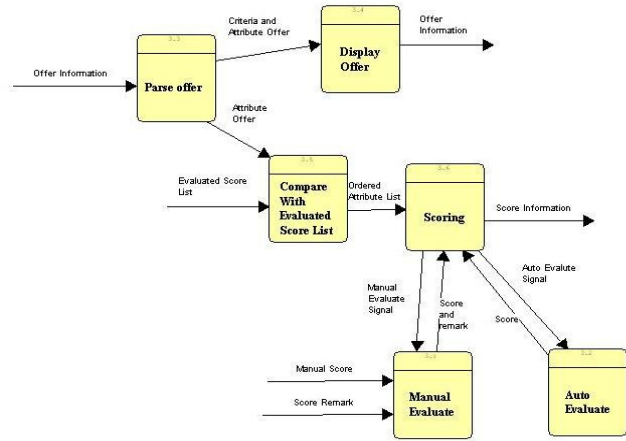


Figure 5. Tender evaluation in two modes.

4.1 Evaluation Process

Once the evaluator starts the evaluation process, the tender offer is first parsed and attributes of the offers are retrieved. Evaluator can choose to evaluate the offer either manually or automatically. In a manual evaluation mode, the 'Scoring' sub-module will ask for the scores input for each attribute of the offer from the evaluator explicitly; an overall score will be computed according to the corresponding weights preset in the tender creation process. Otherwise, evaluation can be done automatically. Based on the attribute type and the algorithm which is shown below, each attribute is evaluated with a score produced. The individual score from each attribute contribute to the overall score of the whole tender offer. The overall score is the weighted sum of all the attribute offer scores.

Evaluate Offer (automatic):

```
CriteriaList = GetAllCriteria(Tender ID)
for each Criterion in the CriteriaList {
    for each Attribute In the Criteria {
        OfferList = GetAttributeOffer (Attribute)
        if (Attribute Type is Amount) {
            if (Attribute Prefer is the more the better)
                ArrayList RankList = GetRank(OfferList,DESC);
            else
                ArrayList RankList = GetRank(OfferList,ASC);
            Rank = RankList.FindUserRank(User);
            if (RankList Count > 0 )
                Tmp = 10 / Rank
            score = (float)Point * (RankCount - Rank + 1);
        } else
            if (Attribute Type is Time ) {
                if (Attribute Prefer is The later the better) {
                    ArrayList RankList = GetRank(OfferList,DESC);
                    score = (float)Point * (RankCount - Rank + 1);
                } else
                    ArrayList RankList = GetRank(OfferList,ASC);
                    Rank = RankList.FindUserRank(User);
                    if (RankList Count > 0 )
                        Tmp = 10 / Rank
                    score = (float)Point * (RankCount - Rank + 1);
            } else if (Attribute type is Enumeration) {
                Score = Ratio
            }
        }
    }
}
```

4.2 Contract Selection

After all the tender offers are evaluated, the overall scores are sorted in a descending order for the tenderer to determine the final tender winner(s). The pseudo code is given below. Here we also consider the need to have multiple tender winners, which is quite common in e-Government procurement process, so that no single supplier is monopolizing all the jobs.

To facilitate the tender allocation among multiple winners, two allocation modes are proposed: *cooperative allocation*, and *competitive allocation*. During the tender creation, the number of winners intended and which allocation mode to be used would have been decided.

Contract Selection:

```
Switch (Winner Type ) {
    case Single :
        MaxScore = FindMaxScore(RFTID);
        WinnerList = Find the Winner with the Max Tender Offer Score
    /// There are more than one having the Max Score
        if (Winner List > 0 ) {
            Winner = Random Get The Tender From the Winner List
    ///Assign all Price Item to this winner
        for each Price Item in CriteriaList {
            Assign the Winner supply this Price Item
    case Cooperative:
        for (each Price Item in Criteria list){
            Criteria_MaxScore=FindMaxCriteriaScore(RFTID,Criteria);
    /// Find the winner with the Max Score
            WinnerList = Find The Supplier with the Max Score of this Price Item
    /// There are more than one having the Max Score
            if (Winner List > 0 ){
                Winner = Random Tender From the List base on Tender Score
    ///Assign this Price Item to winner
                Assign the Winner supply this Price Item
            }
        } break;
    case Competitive:
        Calculate Composite bid
        Cut off = Setting the Cut off Point
        WinnerList = The winner that have lower price than Cut off Price
    ///Setting the Actual Quality Request
        for (each Winner in WinnerList ){
            if (Allocation type is Average ) {
                Assign Quantity Averagely to this Winner
                if (Have Remainder )
                    Remainder Assign from the High Score to Low Score
            }
            else {
                Assign Quantity According to Score Ratio to Winner
            }
        }
        break;
}
```

4.2.1 Cooperative Allocation

In cooperative allocation, the final tender offer is split and arranged in different combinations until a combination that comes with the highest score can be obtained. Here we assume that the tender is a composite tender which can be considered as a bill-of-materials. We also assume that the relevant tenderer is willing to offer a single part, or a set of parts required in the composite tender, if he/she is chosen by the tenderer as one of the multiple winners. Without these assumptions, the cooperative allocation would be considered infeasible in the real scenarios. In case of more than one supplier with the highest score for a certain attribute, one of them will be selected randomly.

4.2.2 Competitive Allocation

In competitive allocation, assume that the composite tender is a set of different items requested, each with associated weight. Tenderer provides the price for each item in the composite tender. The offer is then evaluated as a whole to obtain a composite bid score. A cut-off score is needed from the input of tenderer in order to select the multiple winners. Tenderers with composite bid score lower than the cut-off score will be selected.

Below is the pseudo code for calculating the composite bid score, which is the weighted sum of the tenderer's bid for the various items requested in the tender. After obtaining the cut-off score from the tenderer, an adjustment ratio is derived to calculate the unit price of a certain item. Every tender winner is then required to supply the item at the unit price calculated.

Calculate composite bid:

```
for Each Tender Offer{
    /// Find Out the Price Item and Calculate Composite bid Value
    ///Composite Bid[i] = Item1 ($) * Weight1 + .....+ ItemN ($) * WeightN
    for Each Price Item {
        Sum += Criteria Price * Criteria Attribute
    } Composite bid [i] = Sum }
    ///Min Composite Bid Value < CutOff Bid Value < Max Composite Bid Value
    Cut Off = Get The Cut Off Point
    Adjustment Rate[i] = Cutoff Bid ÷ Composite Bid [i]
    /// It's Offer is Below the Cut off Point
    Winner = Composite bid Value < Cut Off bid value
    for each Price Criteria Item{
        for each tender Offer in the Winner List{
            Sumprice += Criteria Offer * Adjustment Rate
        } UnitPrice = Sumprice / Winner Count;
    }
}
```

The allocation of the amount of each item to a certain winner depends on whether an average allocation or a ratio allocation is selected. In case of an average allocation, all the item demands are divided evenly among the multiple winners. Otherwise, a ratio is specified by the tenderer, and the demands are allocated proportionally. This means that the higher composite bid score the tenderer has, the more amount of the items will be allocated to the tenderer.

A snapshot of the data flow diagram in Figure 6, shows how tender offers are scored and allocated.

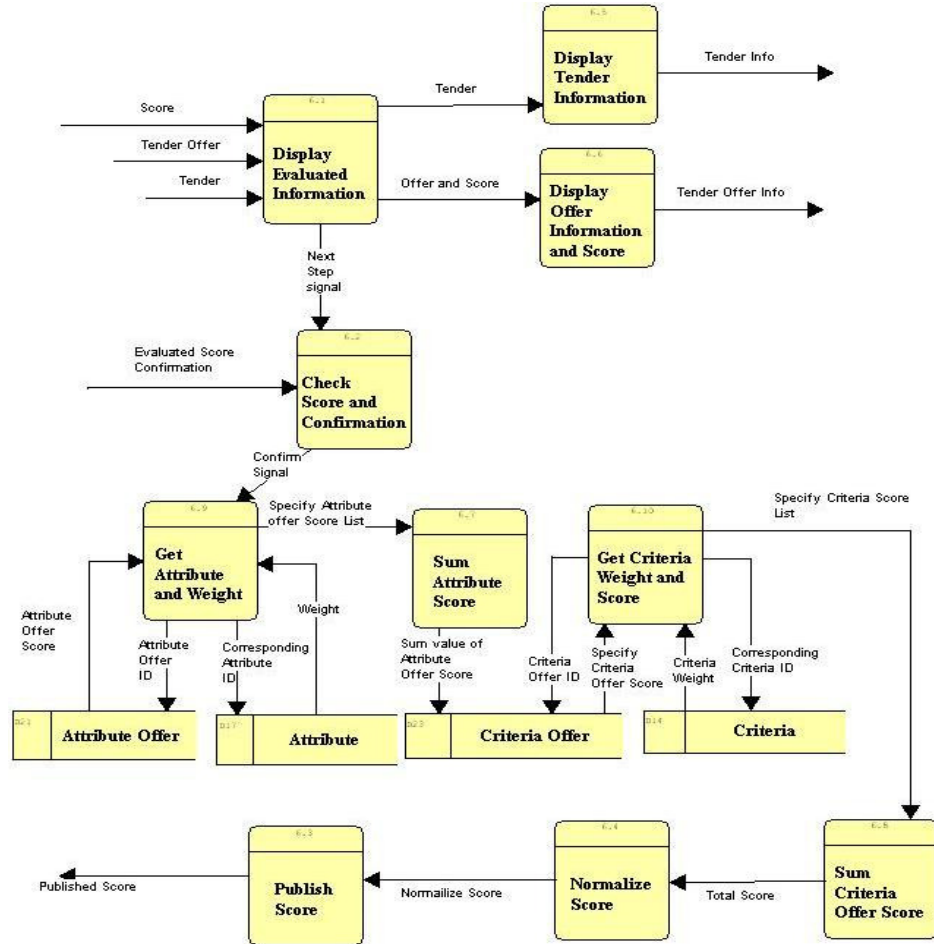


Figure 6. Tender evaluation by different scoring and allocation schemes.

5. PERFORMANCE MODELLING

A prototype is built that illustrates the technological possibilities of implementing WTS. Before it can be adopted by in real-life use in e-Government, there are a number of managerial and technical issues to be concerned over, such as privacy, data-integrity, security, usability, operational costs and performance. In this paper, we shed some light in the technical aspects, in the anticipated performance gain in using the WTS. We used a simulation tool for Business Process Re-engineering to evaluate our proposed WTS model. BPR allows us to model and compare tendering situations, hypothetically, before and after WTS was adopted. It enabled us to check the performance by synthesizing some simulated runs over the models. The obvious advantage is that we can study about the WTS models without incurring costs for actual implementation. Modifying the parameters or even the logics of the flows can easily be done on the fly.

As shown in Figure 7a and Figure 7b respectively, the traditional tendering process which heavily relies on manual work is reflected in the “As-Is” model, and our proposed WTS model which emphasized on automation is in the “To-Be”. The software too we used is called Holosofx Inc Workflow BPR, academic edition that run on a platform of Microsoft Windows XP, and Intel Atom CPU N270, 1.6Ghz.

The tendering process in the “As-Is” model includes certain steps which require a lot of man-power and paper works. For example, the submitted tender offer from the bidders, the tenderee (proxy web) have to print and deliver by human hand, to professionals, which we referred them as Committees, joined by various personnel from certain departments of the government to assess and judge its legality, feasibility and suitability via numerous meetings. In the process flow of our system, we have digitized these steps; the committee personnel can online collaborate into evaluating the tender offers over an Intranet. The power of WTS comes in not only delegating the open bidding to a web front, but to streamline the backend processes in government departments which are still largely in manual efforts and paper-based. It is believed that WTS and its integration and automation of backend workflow would be an important step towards the goals of e-Government.

By traversing the possible branches of the e-Tendering processes as in Figure 7, we assume usually there are seven cases with higher possibilities for those common processes that occur frequent; and relatively lower possibilities assigned for exceptional cases. By assuming other parameters such as process time and human resource cost per hour, as realistically as possible, we have the simulation data in the following table.

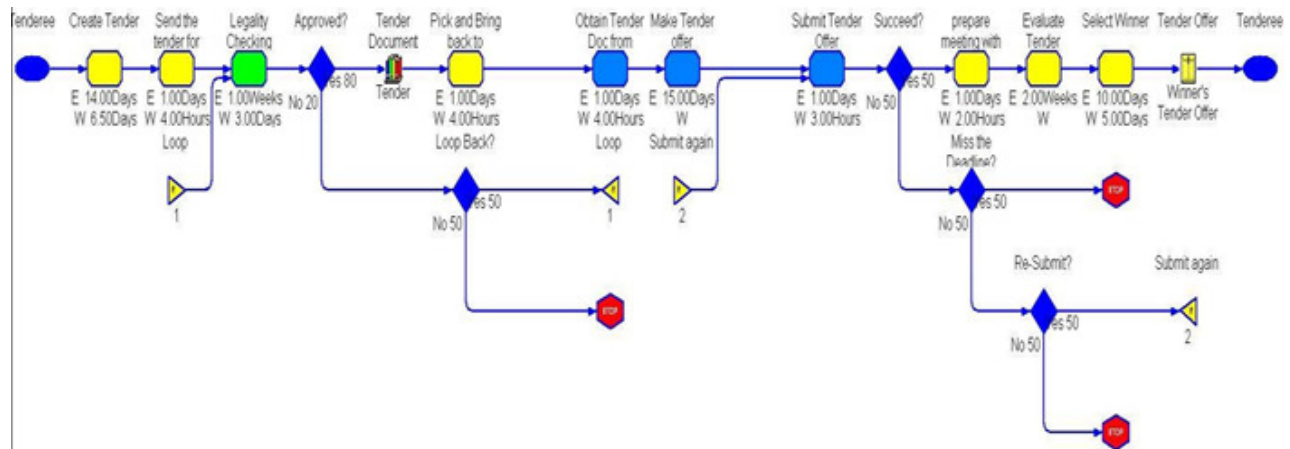


Figure 7a. Workflow diagram of As-Is Model.

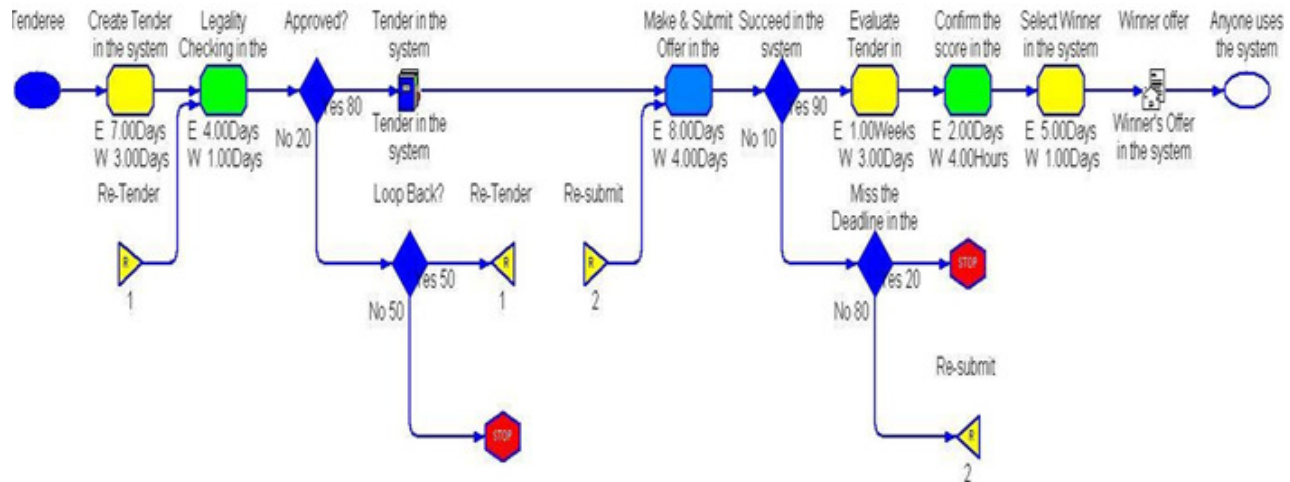


Figure 7b. Workflow diagram of To-Be Model.

Table 1. Parameters used in the case analysis of the “As-Is” process

Process Case Name	Percent	Process Time	External Time	Transfer Time	Wait Time	Working Time	Cycle Time	Resource Cost
Case 1	40.00	59.00h	0.00h	0.00h	27.38h	31.63h	68.13h	Mop35,880.77
Case 2	20.00	60.00h	0.00h	0.00h	28.00h	32.00h	69.13h	Mop36,019.23
Case 3	20.00	38.00h	0.00h	0.00h	16.63h	21.38h	44.13h	Mop19,053.85
Case 4	10.00	20.00h	0.00h	0.00h	10.00h	10.00h	23.13h	Mop11,546.15
Case 5	5.00	64.00h	0.00h	0.00h	29.38h	34.63h	74.13h	Mop40,342.31
Case 6	2.50	43.00h	0.00h	0.00h	18.63h	24.38h	50.13h	Mop23,515.38
Case 7	2.50	65.00h	0.00h	0.00h	30.00h	35.00h	75.13h	Mop40,480.77
Weighted Average	100.00	51.10h	0.00h	0.00h	23.56h	27.54h	59.06h	Mop30,138.56

Table 2. Performance results output from the BPR workflow simulator

Compare Cycle Times

Type of Cycle Time	As-Is	To-Be	Diff.	% Change
Cycle Time (hr)	59.06	34.28	24.78	41.96%
Minimum Cycle Time (hr)	32.04	13.88	18.16	56.68%

Compare Processing Times

Type of Processing Time	As-Is	To-Be	Diff.	% Change
Process Time (hr)	51.10	29.76	21.34	41.76%
Wait Time (hr)	23.56	17.80	5.76	24.45%
Working Time (hr)	27.54	11.96	15.58	56.57%

Compare Total Times

Type of Total Time	As-Is	To-Be	Diff.	% Change
Total Process Time (hr)	51.10	29.76	21.34	41.76%
Total Working Time (hr)	27.54	11.96	15.58	56.57%
Total Wait Time (hr)	23.56	17.80	5.76	24.45%

Compare Resources

Type of Resources	As-Is	To-Be	Diff.	% Change
Labor Time (hr)	27.54	11.96	15.58	56.57%
All Resources Time (hr)	76.38	33.45	42.93	56.21%

From the results shown in Table 2, we verify that when the processes are digitized and integrated as a workflow, there are total gains up to 56% over the manual processes. The cycle time shortens to 42% that translates to sooner the responses the government can reply to the customers. Most importantly, this simulation serves as an example of one possible configuration of WTS and its workflow processes. One can follow this example and simulate other scenarios that are suitable to a particular government situation in which WTS is planning to be deployed.

6. CONCLUSION

e-Tendering is about using technology to its fullest to facilitate tendering process online. Decades ago the development was mainly on digitizing the tender documents and publishing them on a website for public announcement. Recently much effort was contributed to programming the tendering mechanisms and other uses of ICT to support users to participate in tendering online. It can be seen that commercial packages are available as well as many papers in research community arise in the area of e-Tendering. As the literature survey shown in this paper, technology for particular aspects of e-Tendering are available, from intelligent decision support for choosing winners to automated negotiation. What lacks now may be a flexible software architecture that could potentially encompass the new technology in place. On the other hand, it was highlighted in this paper that e-Tendering is more than a front-end website on which suppliers are invited and bidding takes place. From the perspective of the e-Tendering owner who is usually the tenderer posting up tenders for quotations solicitation, a large amount of backend processes follow behind the scene in the e-Tendering cycle. In the context of e-Government who is one of the major users of e-Tendering, the back office processes are bureaucratic. The main contribution of this paper is a design of Web-based Tendering System (WTS) that consists of evaluation module and committee module, aiming at providing efficient use for the users dealing at the back-office processes. It could possibly be extended to full office workflow automation as a whole integrated e-Tendering solution. Furthermore an example of BPR on the WTS was modeled and presented in the paper for verifying the advantages of full e-Tendering process automation. Concerns over changing the internal processes and policies do exist albeit the technology is readily available. A prototype of WTS is implemented and a demonstration is possible by contacting the authors.

7. REFERENCES

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