# A Discrete Event Simulation Model for Awarding of Works Contract in the Government – A Case Study

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## ABSTRACT

*Government departments procure a large variety of products and services in order to carryout its normal operational responsibilities and to implement various plans and policies. For effectively execution of these tasks the government asks for quotation (Request For Quotation) from different contractors. After receiving the quotations from contractors a sequence of procedure are followed before the award of contract is done. Which is a lengthy process that even takes months to finally awarding of contracts. So there is a need of analysis of the existing system to know the causes and effects of the high turnaround time of contract awarding process. This paper gives the insight of contract awarding procedure in government.*

***Keywords**:* Tender, RFQ, Discrete event simulation, government procurement

## 1. Introduction

Government departments procure a large variety and number of product and services form private parties in order to carryout its normal operational responsibilities and to implement various plans and policies. Products ranging from office equipments to heavy equipments and from medicines to consulting services, while services range from construction of roads and buildings to installation of electrical substations and from painting to road transport services.

Government departments rigidly follow the procedure given in "Indian contract act, 1872" to procure goods and services required by them. For a large time, they had been following a manual method of procurement. During the last decade, however, there is a conscious attempt towards electronic procurement of goods and services in particular tendering, one of the procurement process, is being increasingly done by electronic means. The objective of this paper is to:

- Classify the procurement auction process employed by the government
- Study the existing tender awarding process in government department and identify various bottlenecks thereof.
- Suggest improvement in reduction of tender awarding process time by implementing some e-procurement process components.

In order to tackle the above-stated objectives the solution approach that we have followed is:

- To develop a Flow Process Chart of the existing process in government department.

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- To develop a Cause and Effect diagram to identify the improvement factor relevant in the context of awarding of tender.
- To suggest improvement in reduction of tender awarding process time with the help of discrete event simulation model.

Next part of this paper focuses on the present procurement process and its weaknesses. That followed by review of literature in the area of procurement process and discrete event simulation. At last, we have also described improvement of tender awarding process time with the help of discrete event simulation and suggest improvement in reduction of tender awarding process time with the help of discrete event simulation model.

## 2. Review of literature

Procurement is basically part of the logistics process (Cooper and Ellram, 1993); Logistics is defined by the council of Logistics Management, as the process of planning, implementing and controlling the efficient, effective flow and storage of goods, services and related information from the point of origin to the point of consumption for the purpose of conforming to customer's requirement Procurement or purchasing is responsible for acquiring all the material needed by an organization (Perry, 1990). According to Wheel (2000, p.16) "Procurement includes all activities required in order to get the product from the supplier to its final destination. It encompasses the purchasing function, stores, traffic and transportation, incoming inspection, and quality control and assurance."

Based on the consumption purposes of the acquired goods and services, procurement activities are often split into two distinct categories. The first category being direct, production-related procurement and the second being indirect, non-production-related procurement. Direct procurement occurs in manufacturing settings only. It encompasses all items that are part of finished products, such as raw material, components and parts. Direct Procurement, which is the focus in supply chain management, directly affects the production process of manufacturing firms. In contrast, indirect procurement activities concern "operating resources" that a company purchases to enable its operations. It comprises a wide variety of goods and services, from standardized low value items like office supplies and machine lubricants to complex and costly products and services like heavy equipment and consulting services. Finding good supplier and measurement of performance of supplier is also very important part of procurement process. Handfield and Nicholas (1999) state that "in effect, performance measurement is the glue that holds the complex value creating system together, directing strategy formulation as well as playing a major role in monitoring the implementation of that strategy" In modern business management, performance measurement assumes a far more significant role than quantification and accounting. According to Donald et al. (1986), overall aim of procurement is to guarantee that an organization has a reliable supply of goods/services.

## 3. Present procurement Process in Government

In this section, we first define the present tender awarding process that followed by classification of government procurement auction. The procurement process starts with creation of indent to approval of indent in the Rural Development (RD) department. Then it moves to Finance Department for estimation of cost to approval of indent. Then information and public relation (I.P. & R.) department is involved for creation and approval of tender. Then the approved tender is backed to I.P& R. and RD department for further verification. At last the tender documents forwarded to RD department for awarding of product/works/service contract to the most eligible contractor. Figure 1, represents the process cycle of awarding of contract in the Rd department of Orissa government.

As there are 30,000 different types of auctions in literature. So it is very important to classify an auction process considering different characteristics with its range and value. There are also many confusions lies with the sealed bid reverse auction, which is well known as bidding through request for quotation in government. So we have classified the present procurement auction process in table 1.In order to improve the understanding of a procurement process that followed in government departments.

### *3.1. Weaknesses of the Present Procurement process in government*

A number of weaknesses are there in the present procurement process in government. They are discussed below:

- Favoritism in the awarding of public contracts (Mougeot and Naegelen, 2005, Carayannis and Popescu, 2003).
- Discrimination in the awarding process of contracts (McAfee and McMillan, 1987).
- Procurement in government is the source of corruption, scandal and abuse of public resources (Liao et al., 2003).
- Inadequately qualified personnel, "transparency" of the procurement process are another source of problems (Liao et al., 2003).
- Complicated procedure and extended relationships (Carayannis and Popescu, 2003).
- Excessive state intervention (Carayannis and Popescu, 2003).
- Absence of clear national IT policy (Carayannis and Popescu, 2003).
- Use of large volume of paper (Carayannis and Popescu, 2003).
- Lack of flexible centralized control (Carayannis and Popescu, 2003).
- Lack of information quality (Carayannis and Popescu, 2003).
- Resistance to change (Carayannis and Popescu, 2003).
- Contract formation takes place before the negotiation with the contractors (Krishna et al., 2004)

### 3.2 Analysis of Cause with the present tender awarding process:

After the exhaustive study of government procurement process, we have identified the various causes led to problem in awarding of tenders. The various Cause and Effects are shown in fig. 2 by the help of "Cause and Effect" diagram.

**Table 1:** Classification of Government Procurement Auction

| Characteristic | Range/Options | Values |
|---|---|---|
| Number of items of a certain good | One to many | Many |
| Number of goods procured | One to many | Many |
| Nature of goods | Homogeneous to heterogeneous | Heterogeneous |
| Attributes | One to many | Many |
| Type of auction | Reverse vs. forward | Reverse |
| Nature of auction | One-round vs. progressive | One round |
| Procurement Auction | Ascending, descending price | Descending price |
| Participation By | Invitation vs. open | Invitation |
| Use of agents | Agent mediated vs. manual mode | Manual mode |
| Price paid by winner | First price vs. second price vs. nth price | First price |
| Price discrimination | Yes, no | No |
| Constraints exist | Implicitly, explicitly | |
| Follow-up negotiation | Yes, no | Yes |
| Value function elicitation | Yes, no | Yes |
| Nature of bids | Open-cry vs. semi-sealed vs. sealed | Sealed |
| Bid vector | 1, 2, or n-dimensional | N-dimensional |
| Bids divisible | Yes, no | No |
| Bundle bids allowed | Yes, no | Yes |
| Reserved Price | Yes, no | Yes |
| Number of bid evaluation stages | 1,2, or n-dimensional | N-dimensional |
| Pre bid meeting | Yes, no | Yes |

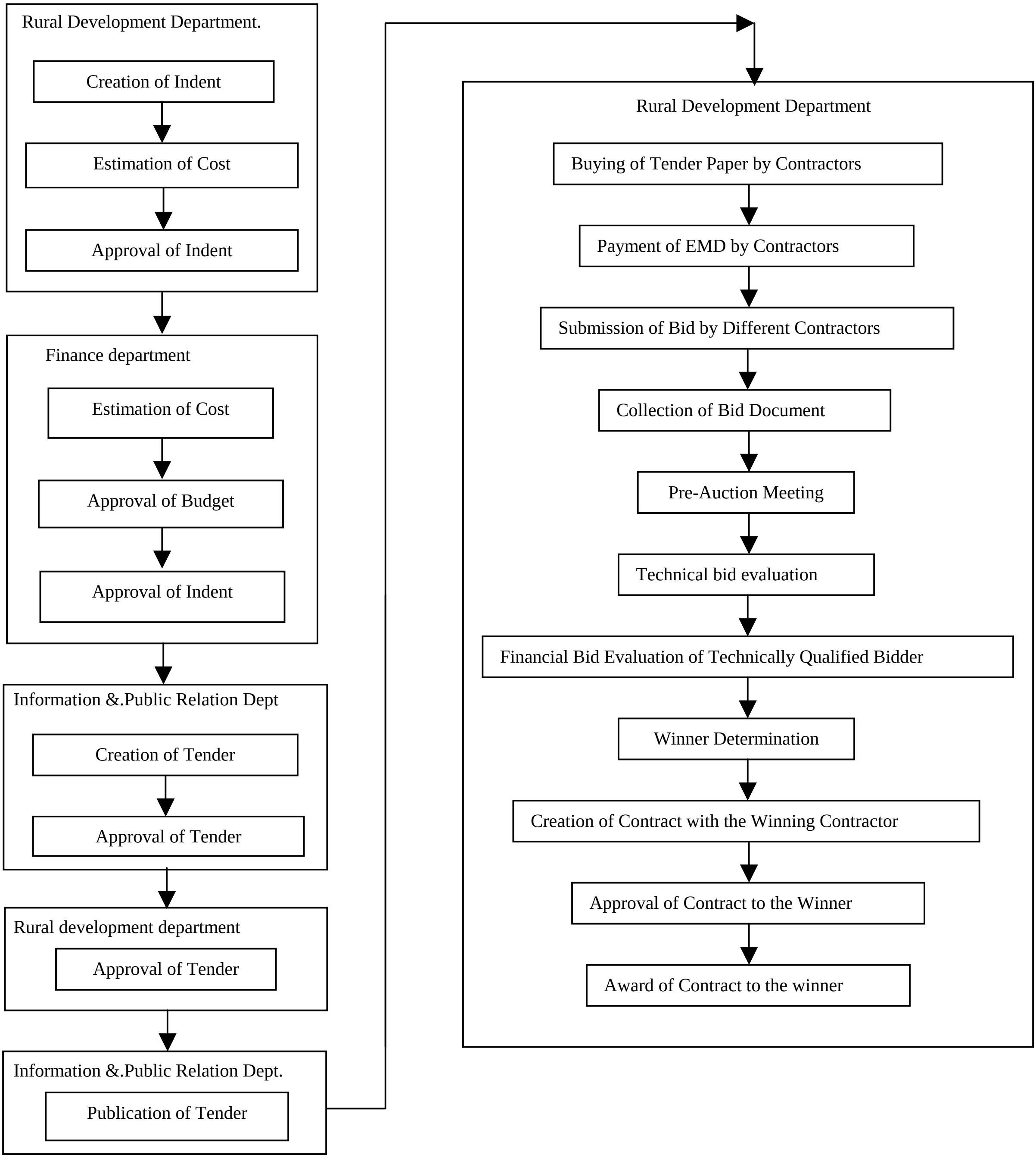


**Figure 1:** Work flow diagram of Procurement process followed in government for issuing of works/service contracts

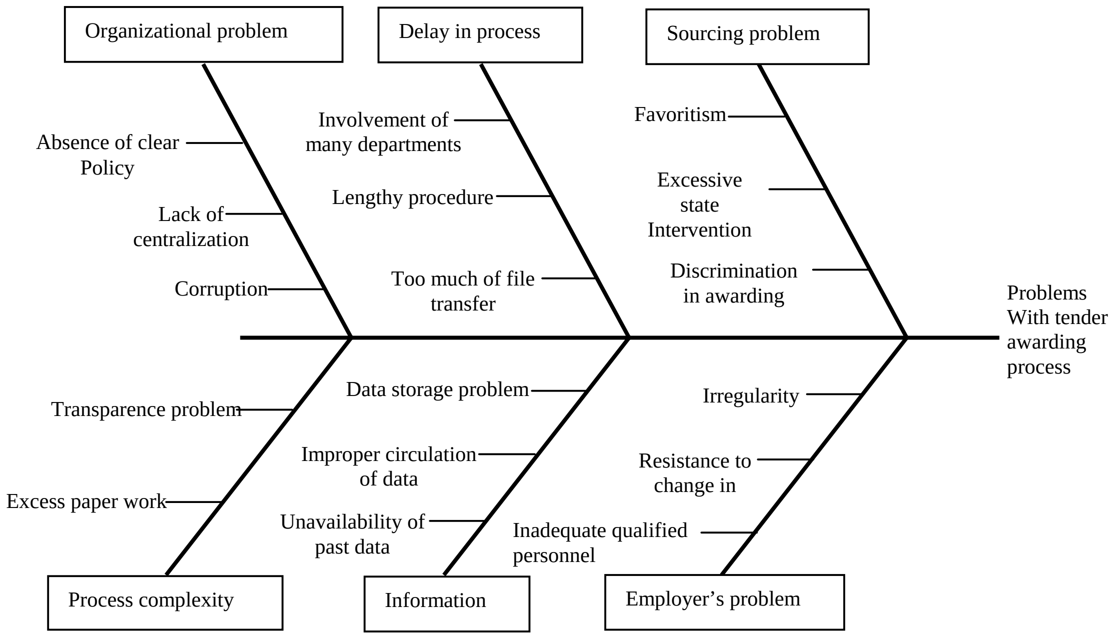


**Figure 2:** Cause and Effect diagram of problems in government tender awarding process

## 4. Simulation Modeling and Analysis

Simulation modeling and analysis is the process of creating and experimenting with a computerized mathematical model of a physical system. Simulation is used to visualize behavior, to identify problems and to improve performance of a system (Banks *et al.,* 1997). Pegden *et al*. (1995) gives the areas of application of simulation modeling and analysis. The successful implementation of simulation modeling are visible in application like gaining insight into the operation of a system, developing operating or resource policies to improve the productivity, testing new concepts and/or systems before implementation, gaining information without disturbing the actual system. Discrete-event systems (DES) simulation approach allows different combinations of decision strategies to be evaluated and thus provide adaptively necessary for efficient use in dynamic, on-line environments (Fishman, 2001; Bratley, 1987).

According to Saad and Kadirkamanathan (2006), procurement in a supply chain is managing the flow of materials and products from the source to the user. This flow typically includes aspects of purchasing, manufacturing, capacity planning, operations management, production scheduling, manufacturing requirements planning, distribution system planning, transportation systems, warehousing and inventory systems, and demand input from sales and marketing activities. Simulation provides an alternative method for detailed analysis of the complex real world systems such as the procurement. Given that a simulation model is well-suited for evaluating dynamic decision rules under 'what-if'' scenarios, a few attempts have been made to develop simulation models to improve procurement performances." According to Chwif *et al.* (2006) 'Discrete-event systems (DES) simulation models are also a very popular approach for procurement process related problems. This simulation approach allows different combinations of decision strategies to be evaluated and thus provide adaptively necessary for efficient use in dynamic, on-line environments.'

*Input data collection and analysis*

This phase of simulation is often considered the most difficult. Data may be collected from historical records or can be collected in real time. In order to observe data in a simulation model, it must preferably first be fit to a theoretical distribution (Banks *et al.*, 1997). The theoretical probability distribution is then used to generate values to drive the simulation model. In order to determine the best theoretical distribution fit we have collected data of 30 contracts during the year 2000 to 2007 for fitting of distribution (Chi Square, Kalmogorov Sironov (K-S), and square error methods test) in table 2.

**Table 2:** Expressions of different input processes that are used in the simulation

| S. No. | Process name | Expressions | Distribution | P Value | |
|---|---|---|---|---|---|
| | | | | Chi Square | K-S |
| 1 | Create indent | POIS(7.15) | Poisson | 0.343 | > 0.15 |
| 2 | Approve indent 1 | 0.5 + ERLA(3, 3) | Erlang | 0.75 | > 0.15 |
| 3 | Estimate cost | UNIF(5, 10) | Uniform | 0.0533 | > 0.15 |
| 4 | Approve budget | NORM(3, 1) | Normal | 0.872 | > 0.15 |
| 5 | Approve indent 2 | UNIF(3, 7) | Uniform | 0.0658 | > 0.15 |
| 6 | Create tender | 0.15+17*BETA(0.729,0.925) | Beta | 0.698 | > 0.15 |
| 7 | Approve tender | UNIF(2, 5) | Uniform | 0.0935 | 0.0318 |
| 8 | Publish tender | 0.5+13 * BETA(0.131, 0.472) | Beta | 0.544 | > 0.15 |
| 9 | Buy tender | 1.5+WEIB(8.1,1.18) | Weibull | 0.75 | > 0.15 |
| 10 | Bid submission | 0.5+LOGN(3.8,5.11) | Log-Normal | 0.0191 | > 0.15 |
| 11 | Pre auction | 0.8+18*BETA(1.02,2.43) | Beta | 0.063 | > 0.15 |
| 12 | Technical evaluation | 0.5+15.5*BETA(0.97,1.72) | Beta | 0.75 | > 0.15 |
| 13 | Commerce evaluation | 0.3+15*BETA(1.3,1.76) | Beta | 0.434 | > 0.15 |
| 14 | Create contract | 3 + 7 * BETA(1.05, 1.34) | Beta | 0.692 | > 0.15 |
| 15 | Approve contract | UNIF(1, 3) | Uniform | 0.0861 | > 0.15 |

*Starting Conditions*

The simulation starts with an empty state of system as it does in reality. The first entity is created at 10:00 am that is the office-opening hour in government departments of the Orissa government. After replication length of 67 days the model turns back to the original state.

*Terminating Event*

There is no natural termination of event for this simulation model. The simulation terminates after successful completion of replication length of 67 days.

*Measure of Performance*

These are the indicators of performance of the system. The awarding of tender time is the important output measure of performance for this study. Tender awarding time is the total time spent by a tender document from creation of indent to award of contract. The primary aim of this work is to reduce this tender awarding time.

*Assumptions*

A few underlying assumptions were incorporated in the modeling of the system (Chung, 2004) they are stated as under

- No Balking: The first assumption states system entities cannot balk. This means that in order to obtain access to the system, all entities must proceed through the each serving counters.
- No Jockeying: The second assumption states system entities do not jockey. Jockeying is jumping between queues if another queue becomes shorter in length.
- Queue Selection: When presented with more than one queue, it is assumed that the system entities will not select the shortest queue.
- Size of Queue: It is assumed that the system will not shut down the system regardless of how long

a system queue becomes.

- Service Rate Is Independent of Queue Size: It is assumed that during service, the number of entities waiting in a queue will not result in serving channels changing work method so that the entities system time is reduced.
- No unconcern orders are discovered: The discovery of an unconcern orders is not a regular occurrence. Thus, this situation is outside the scope of this model.
- No Breaks: It is assumed that, all serving processes will remain on duty without taking breaks.

*Model Translation*

The formulated conceptual model is needs to be translated to a simulation model. The model translation starts with selecting a simulation software package or general purpose programming languages for modeling the system and performs the actual process of programming the model. Simulation models can be represented in many simulation languages. Arena 10.0 has been chosen in this project for representing the system (Kelton *et al.,* 2004). This component is used to statistically analyze and compare output measures of performance.

*Simulation Model and output*

The conceptual system model was translated to simulation model by incorporating the assumptions, operating parameters, tactical consideration delivered from model formulation. The fig below shows the simulation model.

The simulation model developed above imitates the actual tender awarding process. The flow of the document in the model is initiated by a create module which generates the document following the theoretical probability distribution of the inter-arrival rate of the documents. The delay module captures the process event delays of documents transfer.

The document file flow through series of official channel namely create indent, estimation of cost server, approval of indent server, approval of tender server (entry and exit) are captured by the process module which also keeps tracks of the queuing parameters of these servers. The process module also allots a resource to each of the server and collects the resource statistics. The decision module was used to check any given condition and crack the decision by chance while selecting one from the number of servers. The delay module showed the file transfer within the department and the transfer time was marked as value added activity. The final awarding of tender to the contractor is depicted by dispose module. The statistics module and record module were employed to collect the model statistics.

## 5. Model Validation

After successful translation of the conceptual model to a simulation model, the simulation model is validated. Validation is defined as the process of ensuring that a model represents reality at a given confidence level. Validation confirms simulation model as a reasonable representation of the actual system. There are two major types of validation test, the first of these is face validity which means that the model, at least on the surface, represents reality and is achieved by demonstrating the model animation to domain experts. The second is statistical validity that involves a quantitative comparison between the output performance of the actual system and the simulation model by application of hypothesis tests (Law and Kelton, 2000). Based on the properties of the data set of the actual system and the simulation model, the flow chart in Figure 4 assists in selecting the most appropriate hypothesis test. For the purpose of definitive test of model validity, thirty random tender awarding times were taken from the actual system from 2000 through 2007. To validate the simulation model first, we conduct the normality test, which is performed on actual tender awarding process turnaround time and simulation model turnaround time (all time units in days), the test gives following results.

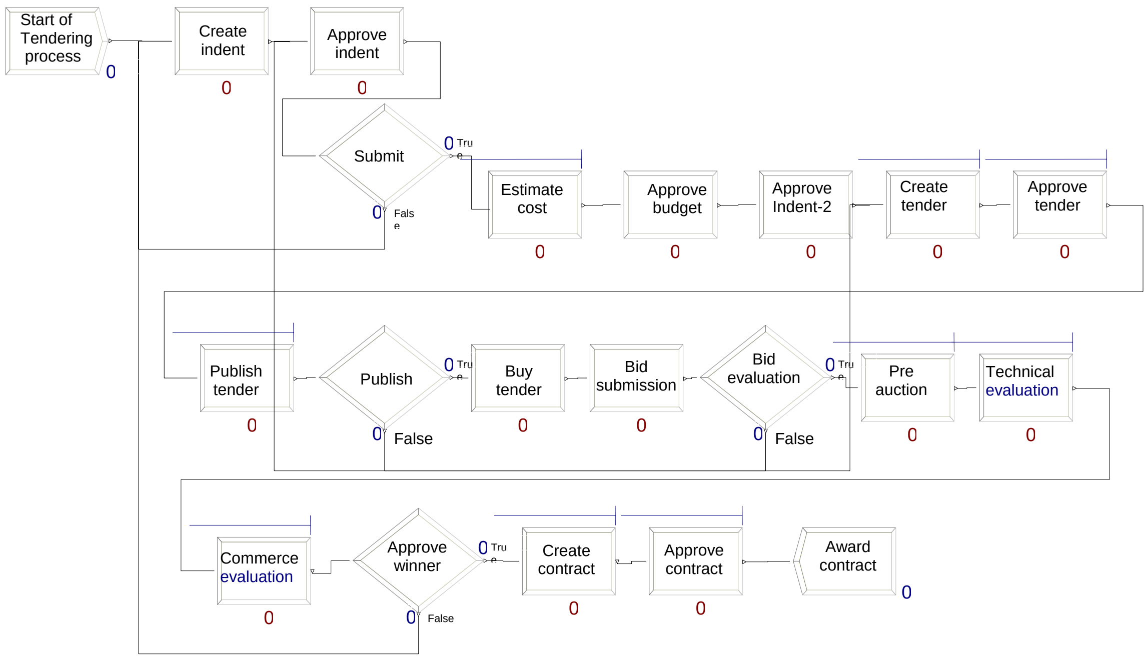


**Figure 3:** Simulation model for issuing of service contracts in government

After the simulation is done the simulated outputs for different entities are presented in Table 3.

**Table 3:** Simulation Output of Process Time Per Entity

| Time per entity | Average time in days | Minimum value | Maximum value |
|---|---|---|---|
| Approve budget | 3.26 | 0.27 | 6.00 |
| Approve indent | 1.00 | 1.00 | 1.00 |
| Approve tender | 3.45 | 2.00 | 4.91 |
| Financial evaluation | 6.48 | 0.35 | 13.74 |
| Create contract | 5.91 | 3.06 | 9.67 |
| Create indent | 1.00 | 1.00 | 1.00 |
| Create tender | 7.36 | 0.17 | 17.13 |
| Estimate cost | 7.81 | 5.05 | 10.00 |
| Pre auction | 6.14 | 1.06 | 15.86 |
| Publish tender | 3.20 | 0.50 | 13.45 |
| Technical evaluation | 6.72 | 0.56 | 14.48 |
| Approve contract | 1.94 | 1.02 | 3.00 |
| Approve indent | 4.72 | 3.02 | 7.00 |
| Bid submission | 4.00 | 0.68 | 25.34 |
| Buy tender | 10.23 | 2.00 | 36.94 |

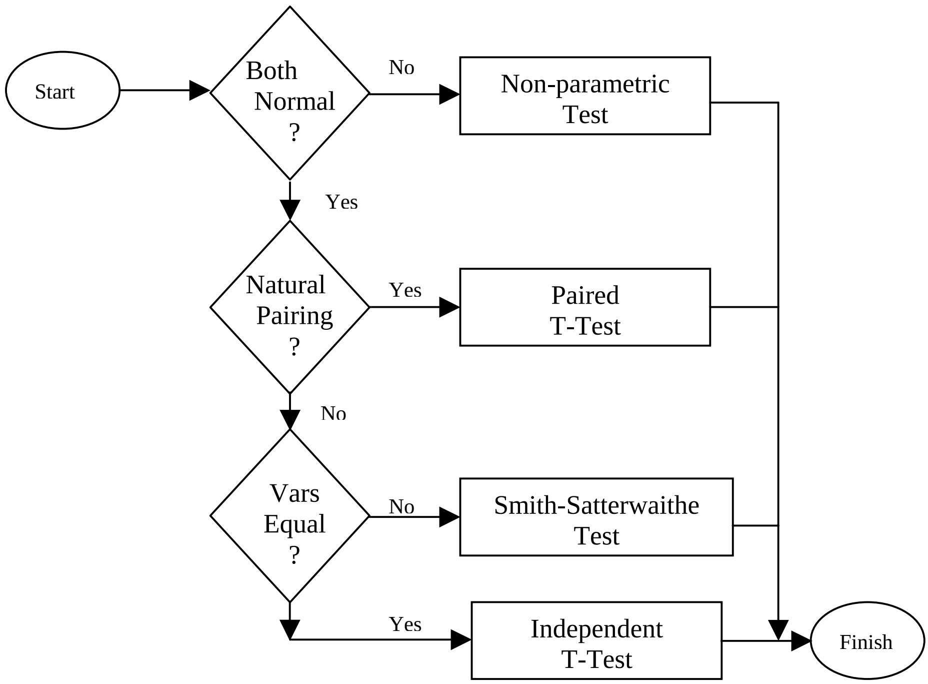


**Figure 4:** Flow Chart for Testing of Hypothesis

As the model and the actual system data, both as together were not normal, a nonparametric rank sum test was carried out to check the validity of the model. The nonparametric rank sum (test methodology discussed in literature survey) test yields the Z value of -1.217 for the two data set under examination while the standard normal 'Z' value for the two-sided test (95 % confidence level) is plus or minus 1.96. Because -1.217 is between -1.96 and 1.96, we cannot reject the null hypothesis that the two data groups are statistically similar.

## 6. Concluding Remarks

As the actual system time and simulation model time are statistically similar, it gives us a conclusion that the simulation model is valid and depicts the reality. The preliminary analysis of existing system revealed that the deficient infrastructure, lack of automation in processing of tender and awarding of contracts, under utilization of official resources, inadequate number of expertise to estimate the cost of work and highly skewed tender evaluation policy were the major cause for high turnaround time. To address the problem and to minimize average turnaround time of a tender awarding process we suggest implementation of e-sourcing, e-contract, and e-catalogue technologies.

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