Chapter 1

Introduction and Literature Review

Procurement is considered as one of the supply chain activities that has very high impact on organizational performance (Lambert and Cooper, 2000), and organizations are increasingly adopting its online version to make procurement even more effective. In the last decade, electronic procurement (e-procurement) has shown a rising trend of application in industry and government (Carter *et al.*, 2000; De bore *et al.*, 2002; Presutti, 2003; Davila *et al.*, 2003; Lin and Hsieh, 2006; Croom and Brandon-Jones, 2007; Ghapanchi *et al.*, 2008), with the government departments lagging behind their industry counterparts. Researchers, worldwide, have shown great interest in (1) identifying the benefits, barriers, and critical success factors for the adoption of e-procurement in government, (2) utilizing the opportunities available in a government setup for proper bidder evaluation, and (3) eliminating the imperfections associated with government procurement in its transition to electronic form. This thesis identifies factors influencing e-procurement in government departments in India, proposes a centralized, multi-attribute bid evaluation procedure for short-listing and/or selecting contractors, forwards a mechanism for detecting bidder collusion, and optimally designs auction parameters to minimize collusion effect in government departments in a state of the Republic of India.

1.1 Government procurement

Government departments procure a large variety and number of goods and services in order to carry out their normal operational responsibilities and to implement various plans and policies. Products range from office equipment to heavy machinery and from medicine to aircraft, whereas services range from construction of roads and buildings to installation of electrical substations and from painting of walls to road transport services.

1.1.1 Importance of procurement in government

Government procurement typically accounts for 10–15% of GDP for economically developed countries, and up to as much as 20% of GDP for developing countries like India (Srivastava, 1999; Global Trade Negotiations, 2006). As per the International Monetary Fund Report 2006-07, India's government procurement agreement is 23% of its GDP, amounting to 960 billion dollars. Sharma (2007) has reported that more than 100 billion dollars of procurement had been done by the Indian government in the year 2005. Furthermore, the government procurement system administers money that belongs "to all", and the procured goods and services are intended to serve the public (Cavinato and Kauffman, 2000). In addition, policy makers have a major bearing on procurement practices adopted in government departments (Lian and Laing, 2004), and policy makers always invite effective policies from various sources—consultancies, foreign-collaborations, and indigenous solutions—to improve the effectiveness of government procurement. Considering the volume and distinct characteristics of procurement in government, an attempt is made in this thesis to study the adoption of e-procurement for government procurement and to improve the procurement process by utilizing various opportunities that the new technology offers.

1.1.2 Weaknesses of the manual procurement process

The government departments in India rigidly follow the procedure given in *"Indian Contract Act, 1872"* (and its various modifications) to procure goods and services

required by them. For a long time, they had been predominantly following a manual method of procurement. A number of weaknesses pervade the manual procurement process in government departments, worldwide and in India. We list a few weaknesses reported in the literature:

1. Use of a large volume of paper leads to a high process residence time in the awarding process (Carayannis and Popescu, 2005; Gupta and Jana, 2003; Mitra and Gupta, 2007).
2. Absence of a clear national IT policy for awarding work contracts and lack of information on the characteristics of the procurement auction create problems for the contractors while submitting the bids (Carayannis and Popescu, 2005; Mitra and Gupta, 2007; Sharma, 2007).
3. Lack of transparency in the award of work contracts is common in government departments (Gupta and Jena, 2003; Liao *et al.,* 2003; Mitra and Gupta, 2007).
4. Excessive state intervention, favoritism towards the local contractors, and discrimination in awarding contracts create problems in the tender awarding process (Carayannis and Popescu, 2005).
5. Procurement in government is usually associated with corruption, scandal, and abuse of public resources (McAfee and McMillan, 1992; Mougeot and Naegelen, 2005; Liao *et al.,* 2003; Mitra and Gupta, 2007; Sharma, 2007).
6. Lack of flexible centralized control by government departments leads to improper standard of bid evaluation methods (Carayannis and Popescu, 2005).

1.1.3 Opportunities offered by e-procurement

To overcome many of the weaknesses listed above, there is a conscious attempt during the last decade towards electronic procurement of products and services. In particular, tendering, one of the elements in the procurement process, is being increasingly done by electronic means in India. We mention below the opportunities which e-procurement in government sectors can offer:

1. It simplifies the procurement process, reduces paper work and transaction costs, and enhances procurement efficiency that helps to reduce the procurement cycle time and process cost (Liao *et al.,* 2002; Subramaniam and Shaw, 2002; Davila *et al.* 2003; Liao *et al.,* 2003; Gupta and Jana, 2003; Dooley and Purchase, 2006; Lin and Hsieh, 2006; Ash and Burn, 2006).
2. E-procurement establishes an open, fair, transparent, and efficient environment for government procurement (Liao *et al.*, 2002; Panayiotou *et al.*, 2004; Dooley and Purchase, 2006; Mitra and Gupta, 2007; Sharma, 2007). Transparent processes and tools improve internal control of the tender-awarding processes and also reduce administrative cost of organizations (Davila *et al.*, 2003; Gupta and Jana, 2003; Ash and Burn, 2006).
3. Many tender awarding processes, such as payment of earnest money, registration of the contractors, and online publication of tenders, can be done by electronic means (Liao *et al.*, 2002).
4. Using electronic procurement operations, a new benchmarking process can be established through robust analysis for proper evaluation of suppliers and manufacturers (Liao *et al.* 2003; Ash and Burn, 2006).
5. Implementation of electronic procurement helps in improving internal and external communication, business transaction, and management of supply chains and alliances (Chan and Lee, 2003; Dooley and Purchase, 2006).
6. Standardization of the bid evaluation process facilitates business opportunities and motivates contractors to participate in the bidding process (Liao *et al.* 2003; Ash and Burn, 2006).
7. It removes domestic barriers to international trade (Carayannis and Popescu, 2005).

Recognizing the weaknesses of the manual procurement process, the benefits of e-procurement process, and the present trend to adopt electronic means, government departments, worldwide, want to adopt the electronic procurement process (Arslan *et al.*, 2006; Mitra and Gupta, 2007; Sharma, 2007; Croom and Brandon-Jones, 2007; Badri and Alshare, 2008). But factors, such as cost of implementation, lack of employee skills, and

risk of electronic procurement, create barriers for such adoption (Gupta and Jana, 2003 and Sharma, 2007). It has, thus, become necessary to carefully evaluate a traditional, manual procurement system that is prevalent in government departments to assess the extent of improvement possible when e-procurement system is adopted. Furthermore, it has also become necessary to reduce the effect of bidder collusion to derive the maximum benefit out of e-procurement.

1.2 Adoption, bid evaluation, and collusion issues in government

1.2.1 Adoption of e-procurement

E-procurement encompasses business-to-business, government-to-business, and government-to-government domain applications and has attracted many researchers (Liao *et al.,* 2002; Liao *et al.,* 2003; Davila *et al.* 2003; Panayiotou *et al.,* 2004; Chu *et al.* 2004; Radovilsky and Hegde, 2004; Reddick, 2004; Dooley and Purchase, 2006; Ash and Burn, 2006; Arslan *et al.*, 2006; Croom and Brandon-Jones, 2007; Badri and Alshare, 2008; Gunasekaran and Ngai, 2008; Ghapanchi *et al,* 2008) to study the benefits, barriers, and critical success factors for its adoption.

Interestingly, although the studies on e-procurement carried out for different countries have addressed similar issues, their findings are markedly different, reflecting the dependence of factors on the unique socio-cultural environment prevailing in each country. For example, a factor, *organization infrastructure*, considered very important for USA (Davila *et al.,* 2003) is not included in the list of important factors for Taiwan (Chu *et al,* 2004). Similarly, *effective management policy* is considered highly important for Hong Kong (Gunasekaran and Ngai, 2008) in contrast to *end-user satisfaction* considered highly important for Taiwan (Chu *et al,* 2004). Furthermore, a factor, *IT skill of the employees*, considered important in Greece (Panayiotou *et al.* 2004) does not appear in the list of important factors for UK (Croom and Brandon-Jones, 2007).

India has not made much progress in implementing e-governance and in adopting e-procurement in government organizations (Gupta and Jena, 2003; Mitra and Gupta, 2007; Sharma, 2007). Exploring the reasons for the slow adoption is therefore very important.

Past studies have listed a large number of factors influencing e-procurement adoption in government organizations. For example, Gunasekaran and Ngai (2008) have identified 18 factors, Croom and Brandon-Jones (2007) have identified 5 factors, Reunis *et al.* (2004) 9 factors, and Yu *et al.* (2008) 5 factors. A study of these factors indicates that many of them have similar directions of influence. And high-leverage factors identified from their standardized regression weights and having similar implications for e-procurement adoption thus may be grouped under one broad category. Such grouping considerably reduces the dimensional complexity of the factors and makes them easily comprehensible. It is also observed that the past studies have not explored the causal relationships among the identified factors which could help formulate very effective strategies to expedite e-procurement adoption in government.

In consideration of the above-made points, the pertinent research questions are:

What categories of factors significantly influence the adoption of e-procurement in government organizations in India?

What are their causal relationships?

The work presented here explores the enabling and inhibiting factors that influence the adoption of e-procurement in government departments (or organizations) in a representative state of India, studies their underlying causal relationships, and identifies the most influential factors for e-procurement adoption.

1.2.2 Information technology readiness

The benefits of e-procurement have significantly enhanced its adoption rate. Its adoption rate is affected by various categories of factors, such as organization structure, implementation-management policies, end-user resistance, and information technology readiness (IT-readiness) of the government departments. Considering these factors, a number of integration approaches and strategies have been put forward in various government organizations (*e.g.*, Angeles and Nath, 2007; Croom and Brandon-Jones, 2007; Badri and Alshare, 2008; and Ahuja *et al*, 2009). But these approaches have been proved to be inadequate in coping with the increasing demand of e-procurement adoption without the support of IT-readiness (Lai *et al.*, 2008).

Technology is the major factor behind productivity improvement (Bahouth, 1994). In this modern era, IT is increasingly being used to improve organizations' ability to effectively use their internal resources. For example, Hafeez *et al.* (2006) and Koh *et al.* (2007) found that organizations which have adopted IT services are reaping great productivity improvements compared to non-adopters of IT. Batenburg (2007) argued that the use of IT is very important, especially for large organizations, to establish effective communication within and across organizations. Furthermore, the use of IT provides opportunities for real-time access of information to all and for improved coordination and collaboration between officials (Ahuja *et al.*, 2009). Its benefits include improved quality of documents, speed of work, better financial control and communication, simpler and faster access to common data, and reduced documentation errors (Nitithamyong and Skibniewski, 2006; Nikolaeva, 2006).

Technology readiness, in short, refers to "people's propensity to embrace and use new technology for accomplishing goals in home life and at work" (Parasuraman, p. 308, 2000). IT-readiness of a government department measures the overall state of the department with regard to initiatives taken to implement IT-based services effectively, and it results from a combination of several enabling and inhibiting factors. Therefore, enabling and inhibiting factors influencing IT readiness of a government department may

coexist, and it should be possible to define and measure the IT-readiness index of a government department considering these factors. The values of IT readiness index can be used to rank the government departments for quantifying their e-procurement adoption potential.

Jaafar *et al.* (2007) determined the technology readiness index of managers of Malaysian construction firms to study the adoption of IT services. Lai (2008) studied the state of technology readiness of professional accounting students in Malaysia to examine the level of their IT skills. Lin and Hsieh (2006) examined the relationship between technology readiness and adoption of self-service technologies in Taiwan and found that they were positively correlated. Massey *et al.* (2007) measured the technology readiness of end-users through online service interfaces of web sites, where web site interfaces depend on contextual factors, type of sites, and access method of web sites. Demirci and Ersoy (2008) have measured the Technology Readiness Index of customers in the adoption of short life cycle products/services and rapidly shrinking technology for sustainability and survival of business in Turkey. All the authors have used the approaches put forward by Parasuraman (2000) and Parasuraman and Colby (2001) to determine the Technology Readiness Index. Using four components (optimism, innovativeness, discomfort, and insecurity), they have compared the means of the responses to a questionnaire survey conducted to identify various factors related to technology readiness.

Parasuraman (2000) and Parasuraman and Colby (2001) have computed individual scores of respondents in a questionnaire survey with regard to their readiness to embrace information technology. Similarly, Lin and Hsieh (2006) and Massey *et al.* (2007) have computed the index at the level of individuals. We consider it highly useful to define and compute an aggregate IT-readiness index at the level of a government department, rather than for each individual employee. Such knowledge helps the management in formulating effective IT strategies for the department.

Past studies (for example, Hafeez *et al.*, 2006; Koh *et al.*, 2007; and Massey *et al.*, 2007;) have identified IT-readiness as the most critical success factor for adoption of e-procurement in government organizations. Researchers have found that the government organizations lag considerably behind private industries in terms of IT-readiness (Gupta and Jana, 2003; and Sharma, 2007). The possible reasons for this is the non-availability of adequate hardware and software resources, inadequate computer skill, lack of effective training programs to upgrade the employee skill, and lack of adequate financial support in case of the government departments. Assessment of IT-readiness of government departments helps the government to select departments with high IT-readiness for implementation of e-procurement in a prioritized manner. It has thus become important to identify the factors that contribute to the IT-readiness of an organization.

In consideration of the above research gap, we have attempted to answer the following research question: *How to measure the IT-readiness index of a government department?*

1.2.3 Bid evaluation

Government departments in India outsource their required works and services through various procedures such as open cry, competitive bidding through Request for Quotation (RFQ), and agreement through negotiation (CPWD manual, 2003). Of these, competitive bidding through RFQ is the most frequently used procedure. It is used for selecting contractors to award construction projects such as those related to buildings, port works, roads, and waterworks.

While asking for competitive bids from potential contractors in an auction, a department brings out a tender notice and publicizes, among other things, the last date of submission of bid documents, the earnest money to be deposited by each contractor to participate in the bidding process, the design (drawing) and technical specifications (type of material and dimensions) for each project, the minimum liquid assets that a contractor must have with him, the reserve price for the project, the minimum amount of work on similar projects (one-third of the reserve price) that a contractor must have had done

satisfactorily in the past, the period of maintenance warranty, the class of contractor[1], and the required physical resources (such as manpower, equipment, etc.) to accomplish the project (http://tender.gov.in, access date: 12th May 2008).

To set the reserve price of a project, the government departments estimate the project cost considering various attributes, such as material cost, machine operating cost, manpower operating cost, geographical location, and market type. They provide 10–15% profit margin over the estimated project cost to arrive at the reserve price, which they publish in the tender notice. The one with the lowest financial bid wins the contract as long as its bid is lower than the reserve price.

A government department follows a two-stage process to award a work contract. In the first stage, it evaluates the applicants and rates them with respect to three main pre-qualification attributes of the technical bids (called here as the present status of the contractor). The three attributes are: (1) Quantum of similar work done in the past, (2) Amount of physical resources available, and (3) Financial status (liquid assets) of the contractor. The department shortlists three highest-scoring bid participants for the second stage of evaluation. In the second stage, the bidder quoting the lowest bid price is declared as the *winner*.

The use of the criterion of the lowest bid price to finally select a contractor has been criticized by many (*e.g.,* Hatush and Skitmore, 1998; Stein *et al.,* 2003; Al-Reshaid and Kartam, 2005; and Dimitri *et al.,* 2006a). According to them, a contractor, quoting a very low bid price and ultimately winning the auction, may find the quoted amount totally untenable. Such a contractor often resorts to various cost-cutting measures, which can lead to serious quality problems. Furthermore, the lowest-bid contractor may have secured the lowest pre-qualification score among the previously short-listed contractors. The selection procedure, thus, does not distinguish a technically vastly superior contractor from other marginally qualified ones.

[1] Contractors are classified into B-, A-, Special-, and Super-class, based on their physical resources and experience of handling projects.

The contractor selection procedure also suffers from two other deficiencies. First, the selection process does not attach any importance to the past work performance of contractors. Having won a contract, a contractor, with a poor record of past work-performance, is very likely to deliver work with poor standard. Holt *et al.* (1995) and El-Sawalhi *et al.* (2007), for example, found the contractors to be unreliable when their past work performance was not considered in the selection process. Second, a contractor can bid for any number of projects at the same time. Because procurement auctions take place in a decentralized manner in government departments, it is quite possible that a contractor wins the award of multiple projects. Such a contractor often fails to handle all the projects satisfactorily due to his limited resources and exceeds the planned schedule and cost and, consequently, compromises on quality. Therefore it is important to propose a contractor short-listing or selection procedure that includes the past performance of contractors and their bids for multiple projects.

1.2.4 Contractor selection models: A review

Many studies have recognized the importance of, and the associated difficulties in, multi-attribute nature of scoring of contractors. According to Dobler and Burt (1996), Beil and Wein (2003), Gallien and Wein (2005), Arslan *et al.* (2006), David *et al.* (2006), Patil (2006), Dimitri *et al.*, (2006a), Dimitri *et al.* (2006b), and Shyur and Shih (2006), consideration of multiple attributes in procurement auction is important, but setting their priorities in a bid evaluation process is difficult. To overcome these weaknesses and evaluate construction contractors in a multi-attribute procurement scenario in the government sector, a number of modeling approaches have been proposed in the literature. Table 1.1 gives a selected set of methods and the contractor selection attributes used in these methods.

Al-Harbi (2001) and Topcu (2004) used Analytic Hierarchy Process (AHP), whereas Deng (1999) used Fuzzy Analytic Hierarchy Process (FAHP) to score the contractors. Both AHP and FAHP techniques check the consistency of expert judgments. Using these techniques, the qualitative scores of attributes are converted into numerical values.

Table 1.1: Contractor selection methods used for construction projects

Author	Country	Selection attributes used	Methods
Deng (1999)	Australia	Quoted cost, technical capability, services and references of the government officials.	Fuzzy-AHP
Missbauer and Hauber (2006)	Austria	Bid price	Integer programming
Lai *et al.* (2004)	China	Contractor organization structure, firm honor and competence, quoted bid price, and amount of materials used.	Multi attribute analysis
Lambropoulos (2007)	Greece	Quoted cost, quality of work, and completion time	Multi-attribute utility theory
Kumaraswamy (1996)	H. K	Financial status, technology offered, and experience in handling similar types of projects.	Performance-based scoring
Wang *et al.* (2006)	Taiwan	Conversion of all the attributes to price	Unit price based
Topcu (2004)	Turkey	Quoted cost, quality of work, and completion time	AHP
Al-Harbi (2001)	U. A. E	Experience in handling similar types of projects, financial stability, quality performance, manpower resources, equipment resources, and current workload.	AHP
Holt *et al.* (1998)	U. K.	Quoted cost, quality of work, and completion time	Cluster analysis
Hatush and Skitmore (1998)	U. K.	Quoted bid price, financial soundness, technical ability, management capabilities, safety performance, and reputation.	Multi-attribute utility theory

The techniques can also handle scores assessed by a group. The contractors are rated subjectively by the decision makers who use the Saaty scale (Saaty, 1980) to convert the scores into crisp numbers and make pair-wise comparison among the attributes as well as the contractors. AHP, however, cannot capture the imprecision of the preference ratings for scoring the contractors. The fuzzy scale, used in FAHP, gets over this problem by allowing the experts to give their opinions in terms of a range of values in the scale. AHP and FAHP suffer, however, from the *rank reversal problem* (Wang and Triantaphyllou, 2008). Such a problem is said to occur when the relative ranks of contractors change whenever one or more contractors are either added or deleted from consideration.

Hatush and Skitmore (1998) and Lambropoulos (2007) have used *multi-attribute utility technique* to score the contractors. In this technique, attribute-level utility scores are determined by comparing the desired value of each attribute (set by the government) with its actual value as achieved by the contractor. The sum of the attribute-level utility scores

reflects the total utility score of the contractor. Thus, the technique has the ability to consider multiple attributes. However, it cannot handle fuzzy data and does not work properly for group decision-making problems (El-Sawalhi *et al.*, 2007).

Lai *et al.* (2004) used *multi-attribute analysis technique* to score the contractors. A simple scoring technique in which the contractors are rated on an ordinal scale, the technique cannot capture the imprecision associated with impressionist preference ratings of decision makers. Also, it does not check the consistency of scores for the attributes by decision makers (El-Sawalhi *et al.*, 2007).

Kumaraswamy (1996) used a *performance based scoring technique* for rating each attribute on an interval scale and for summing the individual scores to compute the final score for a contractor. The technique is simple to use, but it depends on the subjective decisions of the experts. Also, it cannot accommodate attributes with dissimilar scales of measurement. The technique also fails to guarantee consistency in determining the attribute weights.

Holt *et al.* (1998) used *cluster analysis* to group the contractors having similar characteristics. The technique can handle the attributes with dissimilar scales of measurement. Whereas this technique is helpful in short-listing the contractors, it cannot help selecting the most favorable contractor.

Missbauer and Hauber (2006) used a *single-objective (bid price) integer programming* model to select the winning contractor. However, they did not consider other important non-price attributes, such as quality, time of completion, physical resources, and past performance of the contractor.

Wang *et al.* (2006) used the *unit-price based selection method*, where all the selection attributes were converted into a single attribute—price—to select the most favorable contractor. However, mapping multiple attributes to a single attribute—price—is difficult (Teich *et al.*, 2005) and debatable.

In summary, we state the following:

1. Models for procurement auction of construction projects have considered single projects only. Models for awarding multiple construction projects have not been reported in the literature.
2. Procurement auction models have used "pre-qualification" criteria to screen out the contractors. The attributes include physical and financial status of a contractor and the volume of similar work done in the past by him. They do not include effects of past performance-related attributes such as quality of work done and delay in completing past projects.
3. Holt *et al.* (1994a, 1994b, 1995) and El-Sawalhi *et al.* (2007) have used data that can be either qualitative or quantitative for awarding work contracts. However, they did not consider simultaneous existence of both qualitative and quantitative data (Deng, 1999; Missbauer and Hauber, 2006). Also, most authors considered the quantitative data of either inhibiting or enabling nature, but not simultaneous existence of both types of data.

In consideration of these issues, the pertinent research question that this thesis seeks to answer is: *How to develop models to handle award of multiple projects by considering both price and non-price attributes that may be either qualitative or quantitative or both and either enabling or inhibiting or both?*

1.2.5 Collusion

Many studies have confirmed that bidders form cartels in procurement auctions to increase bid price and clinch contracts at the cost of the auctioneers (*e.g.*, Porter and Zona, 1993 and 1999; Bajari and Summers, 2002; Porter, 2005; Harrington and Chen, 2006; Marshall and Marx, 2007; Ishii, 2009). McAfee and McMillan (1992) recognized four types of collusive mechanism to earn profit: (1) Tacit, (2) Coordinative, (3) Transfer, and (4) Budget-breaking. In the *tacit mechanism*, cartel members submit their

competitive bids to the cartel, and the core members decide the winner based on the minimum quoted bid. The remaining cartel members support him by putting phony bids in the auction. However, in some of the cases, the cartel members submit their actual bids in the auction to show synthetic competition among them (Skrzypacz and Hopenhayn, 2004).

In the *coordinative mechanism*, there is no transfer of money or favor, but the bids depend upon the entire vector of reports, *i.e.*, price and non-price factors (McAfee and McMillan, 1992). Following the coordinative mechanism, cartel members coordinate among them by dividing the market.

In the *transfer mechanism*, the cartel members use side payments to compensate the members of the cartel for refraining from submitting phony bids (Pesendorfer, 2000). Generally they use two types of bid scheme, namely rotating and complementing, to allocate contracts in the auctions (Kagel and Levin, 2008). Furthermore, cartel members conduct pre-auction monetary transfer in the bidding-club to restrict competition (Leyton *et al.*, 2002).

In the *budget-breaking mechanism*, the side-payment constraints are relaxed so that transfers sum to zero only on average (McAfee and McMillan, 1992), and cartel members divide the market among themselves. In some cases, cartel members display muscular power and take political advantages to restrict new entrants to the market (Connor, 2001).

The four collusive mechanisms can be broadly classified into two types—presence and absence of transfers, where the transfer can be in the form of money, favor, or support.

Several authors have tried to detect collusion on the basis of bid price information. They have assumed that the patterns in bid prices represent the bidding behavior, and such price pattern can be used to detect collusion. Lang and Rosenthal (1991), Baldwin *et al.* (1997), Aoyagi (2003), and Lengwiler and Wolfstetter (2006) suggested the presence of a cyclic pattern in the winning bids and the presence of specific firms winning specific

types of contracts as pointers to collusion. Lang and Rosenthal (1991) used data mining techniques to find out the cyclic (rotational) winning pattern among the bidders. Baldwin *et al.* (1997) compared the winning bid price pattern of collusive and competitive bidders in the auctions of forest timber contracts using parametric statistics, Aoyagi (2003) used dynamic bid rotation scheme using a game theoretic approach to find out the cartel size. Lengwiler and Wolfstetter (2006) classified different types of collusion schemes and used a scoring technique to score the price and non-price attributes to test the conditional independence for detecting collusion.

Porter and Zona (1993, 1999), Pesendorfer (2000), Bajari and Summers (2002), Bajari and Ye (2003), and Skrzypacz and Hopenhayn (2004), Kagel and Levin (2008) argued that using only bid price to detect collusion may not yield truthful results. They used winning bid price as a dependent variable and distance, utilized capacity, experience of the winning firm, free capacity, and minimum distance of the rival firm as independent variables to build an ordinary least square regression model to detect collusion in school milk market of Ohio, Florida and of Texas and in highway paving contracts of New Work, Minnesota, North Dakota, and of South Dakota. Thereafter, they applied the theory of competitive bidding with asymmetric information among bidders to distinguish between competitive and collusive bidding. They suggested a set of two necessary conditions—exchangeability and conditional independence—to detect collusion among bidders and compare percentage markups between competitive and collusive bidders. The suggested approach is quite rigorous, but the requirement of *a priori* knowledge of bidders who had indulged in collusion and of knowledge of data on five non-price attributes for every bidder makes this approach difficult to apply in practice.

Lundberg (2005) and Brosig and Reib (2007) used non-parametric statistics— run test and Mann-Whitney U test—to compare the collusive and competitive winning bid price patterns. They showed that collusive winning bid price pattern was significantly different from the competitive pattern.

A number of authors (*e.g.*, Lang and Rosenthal (1991), Porter and Zona (1993, 1999), Pesendorfer (2000), Bajari and Ye (2001a, 2001b), Bajari and Summers (2002), Lengwiler and Wolfstetter (2005), Lundberg (2005), and Brosig and Reib (2007)) used the winner bid price pattern to detect collusion along with previously available proven collusive bid data, where collusion was already detected using other empirical means. In reality, availability of collusive data prior to bid opening is not possible. Detection of collusion, even after opening of bid and generation of collusion data in collusive bidding, is very scarce in real world bidding situation. Using parametric statistics with such small size of collusive data is thus expected to lead to erroneous inference. Therefore, detection of collusion from the winning bid price pattern is difficult without the prior information of collusion in the market. To overcome this difficulty, Ishii (2009) suggested the use of the ratio of bid price to reserve price to differentiate collusive from competitive bidding pattern in the Japanese construction market. He used a threshold value of 0.95 for the purpose. However, this threshold value was purely subjective and was not based on any analytical vigor.

In view of the non-availability of a practical method of collusion detection, this thesis seeks to answer the following research question: *How to develop a simple, practical method of detecting collusion in the absence of a prior knowledge of bidder collusion?*

1.2.6 Reduction of collusion effect

Collusion is a major issue in procurement auction, and it is prevalent when the commodity price and the frequency of purchase are high, as in government organizations (Blume and Heidhues, 2006; Menezes and Monteiro, 2006).

In a competitive bidding process, winning bidders often lose financially in a highly competitive situation—known in the literature as the *winner's curse* (Ludema, 2001). In view of the diminishing profit, some bidders tend to adopt illegal means, such as pre-auction collusive agreements and/or post-auction poor workmanship to maximize their profit. To prevent bidders from such nefarious activities, auctioneers usually adopt

several measures. For example, to deal with collusion and tender fixing activities, the government of India has enacted "*Prevention of Corruption Act 1988* (*Act No. 49 of 1988 dated 9th September, 1988*)" which has undergone amendments from time to time. Erring bidders, found engaged in illegal practice to make profit, are liable to be punished under this act. And, to prevent poor workmanship, government organizations usually adopt *yardstick competition*, whereby they continuously monitor and evaluate performance of bidders, and regularly check quality of commodities before sanctioning money to the awarded bidders (Tangerås, 2002), making it difficult for a bidder to earn extra profit through poor workmanship. However, bidders tend to extract profit from collusive agreements, because collusive bidding is difficult to detect. They get detected through external sources, when media, police complaints, and lawsuits filed by opponent bidders help to bring them to light. This scenario is indicative of ineffective collusion detection and control mechanisms in government organizations (Bac and Bag, 2006). Thus, bidder collusion is probably the most serious practical threat to a transparent and effective bidding process.

Several authors (Baldwin *et al.*, 1997; Porter and Zona, 1993, 1999; Aoyagi, 2000; Pesendorfer, 2000; Bajari and Ye, 2001a, 2001b; Bajari and Summers, 2002; Lengwiler and Wolfstetter, 2006; Harrington and Chen, 2006; Albano *et al.*, 2006; Marshall and Marx, 2007; Ishii, 2009) have suggested a variety of approaches to detect collusion—a necessary prerequisite for reducing collusion and/or its adverse effect on the bid price.

1.2.7 Collusion reduction mechanisms

The main causes of collusion are: monopoly of bidders in the market (Dimitri *et al*, 2006a; Carpineti *et al.*, 2006), inadequate number of bid participants in auctions (Huck *et al*, 2004; Ma, 2008), high level of information sharing among bidders (Blume and Heidhues, 2006; De Silva *et al*, 2008), high level of competition among bidders when they have the same potential to get the contracts (Ross, 2004; Ma, 2008), preference of local bidders by the auctioneer (Bajari and Summers, 2002; Dimitri *et al*, 2006a), and corrupt practices of the authority (Tirole, 1992; Laffont and Tirole, 1991; Isihi, 2009).

To eliminate the above-mentioned causes, a variety of collusion prevention mechanisms have been suggested in the literature. Supervisor-monitoring (Tirole, 1992; Laffont and Tirole, 1991), yardstick competition (Tangerås, 2002), design of novel auction mechanisms (Kwasnica and Sherstyuk, 2007; Sherstyuk and Dulatre, 2008), volume of information release **(**Che and Kim, 2009; De Silva *et al.*, 2008; De Silva *et al.*, 2009), splitting of work content (Al-Arjani, 2002), preference to global bidders (Bajari and Summers, 2002), and setting auction parameters and introduction of participation fee and reserve price (Kirkegaard, 2005; Chowdhury, 2008) are some of these approaches. We discuss below the above-mentioned mechanisms in some detail.

Supervisor-monitoring

To reduce the effect of collusion, Tirole (1986, 1992) and Laffont and Tirole (1991) have suggested a three-layer hierarchy (buyer, supervisor, and agent) where a supervisor monitors the agent's (supplier/contractor's) performance. However, the introduction of another layer only shifts the problem rather than solves it, because of high probability of project-related money getting transferred from the agent to the supervisor. To address this problem, Kofman and Lawarrée (1993, 1996) proposed imposition of monetary penalty on the supervisors for their corrupt practices. However, monetary penalties usually fall much short of the social cost of corruption (Bac and Bag, 2006).

To prevent post-auction corruption, government organizations usually adopt *yardstick competition* (Tangerås, 2002). Samuel (2009) suggested that privatizing the law enforcement process can be used to eliminate such post-auction corruption. But these methods cannot be used to eliminate preemptive corruption.

Auction mechanism

Various researchers (*e.g.*, Kwasnica and Sherstyuk, 2007; Sherstyuk and Dulatre, 2008) have suggested multi-objective descending auctions to control collusion in procurement auctions, because in price-only auctions coordination among the collusive bidders is easy and may lead to high project cost for the auctioneer. Coordination among the collusive

bidders in multi-objective auctions requires complex strategies for formulating non-evident objective-wise collusive bids. Furthermore, sealed-bid auctions are found to perform better to prevent collusion as compared to other auction mechanisms (Albano *et al.*, 2006; Carpineti *et al.*, 2006; Dimitri *et al.*, 2006b) because the anonymity among the bid participants eliminates the scope of collusion.

Volume of information release

Che and Kim (2009) suggested that incomplete information (Rasmusen, 2007) among the bidders can be exploited to significantly weaken the collusive agreement among the bidders. Also experimental evidence as well as theoretical arguments supports the intuitive belief that collusion becomes difficult if the auctioneer releases less information about bidders' bidding behavior in the auctions (Blume and Heidhues, 2006). De Silva *et al.* (2008) and De Silva *et al.* (2009) examined the role of information release on bidding behavior using data from highway construction procurement auctions of USA. They found that with the release of project-related information—reserve price, design and drawing specifications, required physical resources, and bidding period—in the tender notice, it is easy for the bidders to estimate the project cost that leads to a decrease in the winning bid price.

Design of auction parameters

Auctions can be made collusion-proof, if at least one bidder is not collusive, or if there are multiple bidding cartels (Hu *et al.*, 2009). To restrict the effect of collusion, many government auction authorities impose floor and ceiling prices. Kirkegaard (2005) and Chowdhury (2008) examined the role of reserve price in controlling collusion in auctions. They suggested that under the appropriate parameter conditions, reserve price allows the auctioneer to prevent the losses due to collusion, if any. But, when the reserve price is set stiff, the number of bid participants decreases due to lower profit margin (Lai *et al.*, 2004) and increases the winning bid price. Roos (2004) developed a game theoretic model and suggested that entry, exit, and investment decisions of bidders have an influence on the collusion environment, *i.e.*, with entry (or exit) of a bidder in the collusive market, collusion decreases (or increases). As the capacities of bidders vary,

collusive agreements also vary (Ma, 2008). Through laboratory experiment, Huck *et al.* (2004) suggested that with two bidders there is some collusion, but with four or five bidders there is less collusion. Also Al-Arjani (2002) validated a widely held hypothesis that with the increase in the number of bidders, the winning price decreases in procurement auctions. He further noted that the average number of bidders increases as the project size increases. However, in India, it is well known that with the increase in the size of the project (work content), pre-qualification level increases that reduces the number of bid participants and makes the auction more vulnerable to collusion.

Several auction theorists have attempted to design or modify an auction in order to generate high revenue (Janssen, 2004). However, in government or semi-government organizations, it is very difficult to change or modify the auction mechanism. In these organizations many factors—tendering procedure, bid period, splitting of work content, and allowable profit margin—influence the auction outcomes. The multiplicity of influencing factors coupled with the averseness of the government to a change in the time-tested auction mechanism makes redesigning the government auction mechanism extremely difficult. In such an environment it is a better strategy to modify the values of auction-related parameters that influence the winning bid price (Ong *et al.,* 2005). Auction parameters influence the auction outcome in complex cause-effect pathways. Thus, while it is easy to estimate the effect of variation of one parameter on the auction outcome, it is quite difficult to estimate the effect of a set of auction parameters on the auction outcome. Furthermore, several authors have concentrated on different aspects of collusion control considering single auction parameters at a theoretical level. No study has been made on reduction of collusion in repeated government procurement auctions considering multiple auction parameters. The relevant research question is: *How can one design optimum auction parameters to reduce (or even minimize) the effect of collusion?*

In the light of the above made discussion, this thesis focuses on e-procurement in government under three broad perspectives: adoption, evaluation, and collusion.

1.3 Objectives and scope of the thesis

Based on the critical findings made in the earlier sections and the research questions posed, the thesis objectives are set as under:

1. To identify factors governing adoption of e-procurement in government departments and establish inter-factor relationships.

   A through literature review is done to identify benefits, barriers, and critical success factors of e-procurement adoption. Based on these factors a questionnaire is designed and surveyed among the government officials. An analysis of the responses to the questionnaire, together with the use of Factor Analysis and Principal Component Analysis, help in framing broad categories of factors. Using these broad categories of factors, hypotheses are developed to find the causal relationships among the categories of factors. The hypotheses are tested in the framework of structural equation modeling.

2. To rate government departments for their IT-readiness and evaluate e-procurement vis-à-vis the prevailing manual contract-awarding procedure.

   The government departments are rated for their IT-readiness in a multi-criteria decision-making (Fuzzy AHP-SMART) framework. Thereafter, benefits of e-procurement are demonstrated using a discrete-event simulation modeling approach.

3. To short-list and/or select contractors for award of projects based on a centralized, multi-attribute procurement process.

   For multi-attribute, centralized procurement, the following approaches are used:

   - *Selection of attributes for contractor evaluation (by literature review, checklist, interviewing officials and contractors).*

- *Determination of past performance score of contractors using Fuzzy-multi utility scoring technique.*
- *Centralized bid evaluation for awarding of multiple projects using fuzzy binary goal programming technique.*

4. To develop a methodology for detecting collusion in government procurement auctions.

   Parametric and non-parametric tests are conducted to detect the presence of collusion.

5. To optimally design auction parameters for reducing the effect of collusion.

   A system dynamics model is developed and tested to explain the scenario of dwindling bidder participation and rising final auction price in real terms. It is used to select the values of policy parameters (by applying the principles of design of experiments) to ensure a comfortable level of bidder participation and a reasonable value of winning bid price.

The scope of the thesis is limited to the following:

1. The studies have been made for the state government departments in India.
2. The thesis is focused on the electronic procurement problems related to the Rural Development Department of the government of Orissa.

1.4 Contributions made by the thesis

This thesis makes the following contributions:

1. It supplements questionnaire survey with exploratory factor analysis and confirmatory structural equation modelling and identifies IT-readiness and Management policy effectiveness as the two most influencing factors for e-procurement adoption in Government departments in India.

2. It combines six IT-readiness attributes of diverse nature—qualitative or quantitative and enabling or inhibiting—to develop and compute IT-readiness index for government departments. And, it combines the individual features of AHP and SMART techniques to measure the IT-readiness indices of the government departments.
3. It demonstrates, with the help of discrete-event simulation, the relative benefit of e-procurement in a government department in terms of improvement in process efficiency and reduced time delay.
4. It proposes centralization of procurement process and inclusion of non-price attributes (quoted time, quoted warranty, and past performance of contractors) to develop a fuzzy binary goal programming model for short-listing or selecting the contractor.
5. It proposes a six-step procedure using elementary statistical tests that divides the bid price-to-reserve price ratios into two clusters, with the cluster having low mean, low variance, and positive skewness signifying competitive bidding and the cluster with the high mean, high variance, and negative skewness more likely to contain collusive bids. When a new auction takes place, the statistical properties of the new bid price data can be compared with those of the competitive bidding cluster to detect irrationality in the bidding behaviour.
6. It introduces a theory of pricing—a theory of determining the winning bid price—based upon number of independent bidders rather than the total number of bid participants, where one who is not a member of any cartel is an independent bidder and a cartel of members represents only one independent bidder.
7. It uses a design of experiment approach in a system dynamics framework to determine values of allowable profit margin, work content, and bid period normal to minimize collusion effect on winning bid price.

1.5 Organization of the thesis

The thesis is organized in seven chapters. The contents of each chapter are presented below in brief.

Chapter 2 summarizes, in a tabular form, the conclusions drawn in the past works on adoption of online processes by organizations in different countries. The chapter also gives the details of the questionnaire survey and presents the analysis of the responses, brings out a list of important enabling and inhibiting factors, and groups them into broad categories. It also uses the structural equation modeling approach to find causal relationships among the broad categories of factors and discusses the results.

Chapter 3 summarizes the factors extracted from a review of past studies. Based on these factors, a questionnaire is designed and pilot tested. A questionnaire survey is carried out among 289 government officials representing 11 state government departments of Orissa. The responses are used to determine the present status of each department. Finally, IT-readiness index of each department is calculated using fuzzy analytic hierarchy process (AHP) and simple multi-attribute ranking technique (SMART). The Rural Development Department secured the highest IT-readiness index. The Department is objectively evaluated, with the help of discrete-event simulation, to demonstrate the relative benefits of e-procurement.

Chapter 4 summarizes the contractor selection attributes extracted from review of past studies and government sources. The attributes are of both price and non-price type that may be either qualitative or quantitative or both and either enabling or inhibiting or both type. The attributes are grouped into two categories—past performance and present status of contractors. To determine the past performance score of contactors a fuzzy multi-criteria decision-making approach is used and to short-list or select the contractor with high utility values in a centralized, multi-attribute procurement process a fuzzy binary goal programming method is proposed.

Chapter 5 develops a methodology for detecting collusion in government procurement auctions using a six-step approach by computing win price-to-reserve price ratios, making a cluster analysis of the win price-to-reserve price ratios, testing the hypothesis of equality of medians and means of clusters, studying the skewness of bid price-to-reserve price ratios in each auction, testing the hypothesis of equality of means and variances for

the clusters considering the bid price-to-reserve price ratios of each auction, conducting an auto-correlation analysis to test the presence of a cyclic pattern among the member-winners. The proposed methodology is also validated by comparing the results with those obtained using the methods proposed by Bajari and Summers (2002) and by Ishii (2009).

Chapter 6 identifies auction parameters that influence the winning bid price and the number of bid participants in government procurement auctions. A cause-and-effect relationship among these parameters is developed. Based on the cause-and-effect relationship (causal model) a system dynamics model is developed. The model is calibrated and validated using different extreme boundary conditions. Thereafter, different policy decisions are tested on the model and model parameter values are optimized by using the desirability function approach in a design of experiment framework.

Chapter 7 summarizes the results, discusses the various limitations of the study, and highlights the scope for future work in the area of e-procurement in government departments.