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Design of a web-based multiagent system for electronic procurement

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Design of a Web-based Multiagent System for Electronic Procurement

by

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ABSTRACT

A novel design of a web-based multiagent system for procurement is proposed. The proposed electronic marketplace (EM) is aimed to enhance the procurement process by acting as an intermediary between buyers and suppliers. The proposed EM consists of users (buyers and suppliers), various components, and a user interface. The components of the proposed EM include buyers' agents, suppliers' agents, a message engine, a decision engine, a knowledge base and a storage of transactions. As part of the decision engine, a prototype supplier selection system, SupplySelect, is developed and implemented. SupplySelect is based on the Analytic Hierarchy Process, a popular multicriteria decision making technique. The user interface includes catalogues, transaction box, help center, resource center, search engine, electronic payments, and trading partners. A case study conducted at Chalmers Suspensions International Inc. illustrates practical implications of the proposed EM, and in particular, SupplySelect.

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Nomenclature

ϕ: Empty task set

$\sum$: Summation

R^+: set of positive real numbers

$\in$: Belongs to

$\equiv$: Equivalent

$\subseteq$: Subset

∂: a deal

θ= pure deal

$\pi = utility_b(\partial) \times utility_s(\partial)$: Product of agents' utilities

AHP: Analytic Hierarchy Process

A_b : identification of the buyer agent

A_s : identification of the supplier agent

A_{cm} : identification of the communication agent

A_{cd} : identification of the coordination agent

A_{kb} : identification of the knowledge agent

A_{st} : identification of the storage agent

B2G : Business-to-Government

B2B : Business-to-Business

B2C : Business-to-consumer

C2G : Consumer-to-Government

C2B : Consumer-to-Business

C2C : Consumer-to-Consumer

C_b : cost function of the buyer agent

$C_b (Y_b)$: cost of finite set of task, Y_b ,of the buyer agent

$C_b (X_b)$: cost of finite set of task, X_b ,of the buyer agent

$C_b (\phi)$:cost of empty task set of the buyer agent

C_s: cost function of the supplier agent

$C_s (X_s)$: cost of finite set of task, X_s ,of the buyer agent

$C_s (\phi)$: cost of empty task set of the supplier agent

C_{cm} : cost function of the communication agent

$C_{cm}(\phi)$: cost of empty task set of the communication agent

C_{cd}: cost function of the coordination agent

$C_{cd}(\phi)$:cost of empty task set of the coordination agent

C_{kb} : cost function of the knowledge agent

$C_{kb}(\phi)$:cost of empty task set of the knowledge agent

C_{st} : cost function of the storage agent

$C_{st}(\phi)$:cost of empty task set of the storage agent

$C(T_{bk})$: stand alone cost of buyer agent

$C(T_{sk})$: stand alone cost of supplier agent

$C_k(\partial)$: Cost of performing tasks by an agent under a deal

DSS: Decision Support System

D_{bk} : a deal for a buyer agent

D_{sk} : a deal for a supplier agent

EC : Encounter Function

EM : Electronic Marketplace

$(EC)_{bs}$: Encounter Function for buyer and supplier agent

E_b: efficiency function of the buyer agent

E_s: efficiency function of the supplier agent

E_{cm}: efficiency function of the communication agent

E_{cd}: efficiency function of the coordination agent

E_{kb}: efficiency function of the knowledge agent

E_{st}: efficiency function of the storage agent

e_{max} : maximum positive eigenvalue of M'

G2G : Government-to-Government

G2B : Government-to-Business

G2C : Government-to-Consumer

IS_{jik} : Individual score of supplier j for sub-attribute k, for attribute i

MAUT : Multi Attribute Utility Theory

MS : Microsoft

M : Matrix M with decision makers preferences

m_{kj}: an element of matrix M

NS : Negotiation Set

O_{db} : desired output of the buyer agent

O_{ab}: actual output of the buyer agent

O_{ds} : desired output of the supplier agent

O_{as}: actual output of the supplier agent

O_{dcm} : desired output of the communication agent

O_{acm} : actual output of the communication agent

O_{dcd} : desired output of the coordination agent

O_{acd} : actual output of the coordination agent

O_{dkb} : desired output of the knowledge agent

O_{akb} : actual output of the knowledge agent

O_{dst} : desired output of the storage agent

O_{ast} : actual output of the storage agent

o_m : option m

OW_i : Overall weight of attribute i

PAR : Problem and Action Report

PD : Postmen and Delivery Domain

$(PD)_{cm}$: postmen and delivery domain of the communication agent

$(PD)_{kb}$: postmen and delivery domain of the knowledge agent

$(PD)_{st}$: postmen and delivery domain of the storage agent

QS : Quality Systems

QPI : Quality cost Performance Index

RFP : Request for Proposals

$Risk_s^t$: risk of the supplier agent at step t

$Risk_b^t$: risk of the buyer agent at step t

s_m : Score of option m

TOD :Task Oriented Domain

$(TOD)_b$: task oriented domain of the buyer agent

T_b : the task set of the buyer agent

$(TOD)_s$: task oriented domain of the supplier agent

T_s: the task set of the supplier agent

T_{cm} : the task set of the communication agent

$(TOD)_{cd}$: task oriented domain of the coordination agent

T_{cd} : the task set of the coordination agent

T_{kb} : the task set of the knowledge agent

T_{st} : the task set of the storage agent

T_{bk} : ordered list of tasks of a buyer agent

T_{sk} : ordered list of tasks of a supplier agent

TS_j :Total Score of supplier j

$Utility_b(\partial)$: Deal's utility to the buyer agent

$Utility_s(\partial)$: Deal's utility to the supplier agent

$Utility_s\ (\partial_s^t)$: utility of a deal for the supplier agent at step t

V': additive value function

w_k: weight of attribute k

$w_{m/k}$: weight of option m with respect to attribute k

W_{ik} : Weight of sub-attribute k, for attribute i

X_b : finite set of task set of the buyer agent

X_s : finite set of task set of the supplier agent

Y_b : finite set of task set of the buyer agent

Chapter 1 Introduction

Information technology, in particular electronic commerce, is playing an increasingly vital role in day-to-day activities. Due to Internet technologies, it is possible for potential buyers and suppliers from distant locations to make transactions at "electronic speed". No industry has been left untouched. Information technology is having a wide impact on supply chain management too. The supply chain management process consists of procurement, manufacturing and distribution of goods. One can see a significant increase in the number of business models using information systems that operate across organizational boundaries. New business models are emerging and old business models are being improved.

1.1 Electronic Marketplaces

A marketplace allows buyers and suppliers to meet at a certain place and at a certain time in order to communicate and to announce buying or selling intentions, which may eventually match and be settled. In the early marketplaces, the trades were barters. The introduction of currency facilitated a fairer exchange of values among the trading participants, but scarcity, urgency and, above all, a lack of free flowing information more often than not led to lopsided deals. Today, however, the world has come a long way in its appetite for goods. Both theoretical advances in economics and the progress of technology have opened up new possibilities.

An electronic marketplace (EM) can be defined as a medium that allows buyers and suppliers to do transactions "virtually" at "electronic speed" and hence reduce transaction cost and time. The primary participants in business transactions are the buyers and suppliers. But, acting as an intermediary, a broker is often also a part of such transactions. The use of the Internet facilitates a broadening of the spectrum of potential commercial activities, information exchanges and opportunities for an EM intermediary. The Economist estimates that there were already over 750 EMs in existence in the first quarter of 2000 (The Economist, 2000). Due to Internet technology, the EM has become more and more interesting because the limiting factors of time and space seem to have been overcome by the new medium. With the help of the Internet, the EM is available 24 hours a day.

EMs reduce the transaction cost drastically (Bakos, 1991). EMs may act: as information systems that help in the free flow of information in the organization (Bakos, 1991); as an electronic procurement solution dealing with supplier evaluation and selection (Segev et al., 1999); as a medium of information exchange; as an intermediary between buyers and suppliers (Dai and Kauffman, 2000); as a listing of specialized products (Bradley and Peters, 1997). Beyond that, some authors argue for special attributes such as virtual EM (Segev et al., 1999), neutral EM (Segev et al., 1999), or open EM (McCoy and Sarhan, 1988). The terms and concepts like Business-to-Business marketplaces, e-hubs, e-markets, e-auctions, and portals seem to overlap and mean different things to different people.

The unique feature of an EM is that it brings multiple buyers and suppliers together (in a virtual sense) in one central marketplace. Buyers and suppliers may go for dynamic pricing. There exist various kinds of EMs and these can be distinguished as: buyer-oriented, supplier-oriented, or neutral EMs; vertical or horizontal EMs; EMs based on pricing and market mechanisms; open or closed EMs; and categorization based on "What" and "How" business purchases. Chapter 2 describes various types of EMs in detail.

However, EMs do not eliminate face-to-face negotiations that are still popular in many small-to-middle scale industries. The combination of face-to-face negotiation and EMs may bring the improved results. As EMs grow, they are becoming cramped by the limitations of other technologies for example Internet technologies, payment technologies etc.

1.2 Supply Chain Management

A supply chain can be defined as a network of autonomous or semiautonomous business entities collectively responsible for procurement, manufacturing and distribution of activities associated with one or more families of related products (Swaminathan et al., 1998). A simple supply chain network is depicted in Figure 1.1 with suppliers at one end and finished goods reaching customers at the other. The aim of supply chain management is to deliver the right product to the right place at the right time for the right price (Kesikinocack and Tayur, 2001).

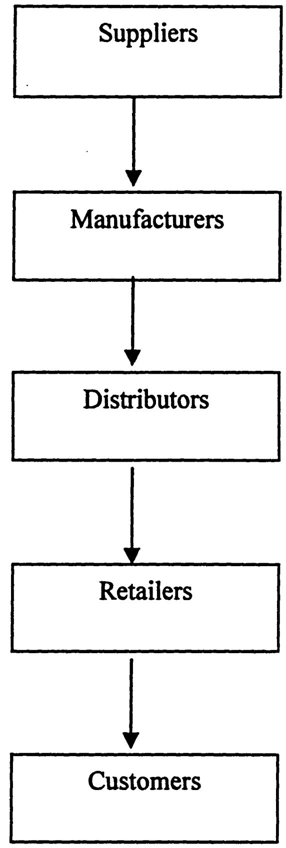


Figure 1.1: Simple Supply Chain Network

Different entities in a supply chain operate subject to different sets of constraints and objectives. However, these entities are highly interdependent when it comes to improving performances of a supply chain in terms of objectives such as on-time delivery, quality assurance, and cost minimization. A basic part of supply chain management is the procurement or purchasing function. One of the prime responsibilities of purchasing is the evaluation and selection of the best supplier (Vokukra et al., 1996). This is true for all types of organizations, including manufacturing firms, and all types of products, including major materials and equipment. The procurement process consists of phases like identification of purchasing needs, sourcing, negotiation and conclusions (Ben Ameur et al., 2002).

Negotiation and supplier selection are the most important phases of the procurement process. The objective of the supplier selection phase is to decide the optimal supplier not necessarily the supplier, offering the best technical services, or the lowest price or the shortest delivery. The decision is a complex process involving various criteria. Chapters 3 and 4 describe the supplier selection process in detail.

1.3 Supply Chain Management and Electronic Marketplaces

The advent of EMs has had a tremendous impact on the modus operandi of supply chain management. EMs have improved the performances of supply chain management entities. The Internet based procurement process is called e-procurement. Many firms, like Emptoris Inc (www.emptoris.com), Mindflow Technologies (www.mindflow.com) etc., have developed their own e-solution providers. The software does the process of e-procurement, which is the initial stage of supply chain management.

Moreover, EMs have speeded up the process of transactions and offer tight connectivity. The buyers and suppliers may transact through the web instead of meeting each other personally. Many researchers have concentrated their efforts on supply chain integration (Kesikinocack and Tayur, 2001). For example, White (1999) discusses the supply chain integration over the Internet which synchronizes supply and demand in real time to maximize revenue and profits to buyers and suppliers.

EMs open up new channels for supply chain management that include direct sales. Direct sales involve selling a company's product through the company's web site (Keskinocack and Tayur, 2001). For example, Dell Computers (www.dell.com) and Cisco Systems (www.cisco.com) are leaders in the direct sales milieu. In 1999, Dell sold $30 million worth of computer gear a day and Cisco handled over 70 percent of its orders through the web. Mindflow Technologies (www.mindflow.com), in close partnership with customers, has helped generate cost reductions in excess of $510 million, with 100% return on investment in 10 weeks. Emptoris (www.emptoris.com) is one of the strong players in electronic sourcing, well positioned to take advantage of a market that will grow from $1.1 billion in 2002 to $3 billion in 2005.

Theoretically speaking, the relationship between EMs and supply chain management appears problematic as the former promotes competition and allows buyers to search for suitable suppliers. However, in practical life, buyers want to sustain long-term relationships with their suppliers. Nowadays, collaborative supply chain management is in progress where buyer and supplier share information through a common information space.

From a practical standpoint, EMs are compatible with supply chain management. Crowley (1998) says that today every business competes in two markets, the marketplace in which resources and products exist physically and in the EM which is virtual world of electronic commerce in which main object of transaction is information. Managing these two interacting value adding processes in two realms is seen as posing new conceptual and tactical challenges for every firm. Gurel et al. (2001) argue that EMs do not eliminate the need for physical logistics systems. The flow of information between supply chain partners can be efficiently managed over an EM increasing the speed and quality of data transfer. The critical use of EMs in supply chain activities can make the process more efficient.

1.4 Agent Technologies in Electronic Supply Chain Management

Agents are computer systems that are capable of performing some flexible, autonomous actions in order to meet its objectives (Jennings et al., 2001). Ideally, agents should be proactive, intelligent, and capable of understanding owners' requirements, and therefore can perform the requisite tasks. Agent technologies have been successfully applied to various domains such as information filtering and job matching. Electronic supply chain management is a popular domain for the application of agent technologies (Ben-Ameur et al., 2002). Indeed many systems have been proposed and implemented for product information retrieval, auctioning, brokering, negotiating etc. (Kia et al., 2002). An important function of the agents is the efficient, accurate and precise search and selection of products a user wishes to purchase. Agents in electronic procurement may be implemented for decision-making processes of supplier selection thereby helping buyers to complete purchasing activity. The agent technology may be extended to automate negotiation tasks. There exist various kinds of agents such as mobile agents, goal oriented agents and communicative agents (Clements et al., 1997).

Various authors have used multiagent approaches to illustrate the importance of agents in automating the supply chains (Swaminathan et al., 1998). The multiagents are applied to various departments of the firm. Some authors have mentioned the concept of autonomous agents (Jennings et al., 2001). Agent technologies are helping buyers and suppliers combine information and expedite specific stages of electronic procurement.

However, there is still some distance to go before agent technologies transform how business is conducted. This change will occur as agent technologies mature to better manage ambiguous content, personalized preferences, complex goals, changing environments and disconnected parties.

1.5 Organization of the Thesis

In this thesis, a novel design of an agent-mediated Internet-based business-to-business EM is proposed that integrates negotiation and decision support systems for the procurement process. The proposed design is based on neutral EMs where buyers and suppliers participate together. This new approach has been proposed where EMs are considered as an intermediary between suppliers and buyers.

The proposed design is well suited for many automotive markets and is comparable to some of the existing business-to-business EMs. The components of the proposed EM consist of buyers' agents, suppliers' agents, a message engine, a decision engine, a knowledge base and storage of transactions. Each agent in the proposed EM is defined in its task-oriented domain. The software agent, in the decision engine, is based on the analytic hierarchy process for supplier evaluation and selection. The principle underlying supplier selection is an amalgamation of additive value function and the analytic hierarchy process. A case study is conducted at Chalmers Suspensions International Inc, a manufacturing firm, which produces automotive transmission gears, suspension springs, and related products. The present and proposed methods of procurement and supplier selection are compared in the case study that illustrates the practical implications of the proposed design.

In summary, the objective of this research is to design a web-based multiagent system for procurement. In Chapter 2, a detailed and critical literature review is conducted on these topics. The proposed design is compared with some of the existing approaches. In Chapter 3, the proposed design of an EM is discussed that includes a description of all its components in detail. In Chapter 4, the implementation of a software agent, SupplySelect, and a case study conducted at Chalmers Suspension International Inc is presented. In Chapter 5, the conclusions are discussed and contributions of the thesis are summarized.

Chapter 2 Electronic Marketplaces and Agents in Supply Chain Management

2.1 Introduction

The world of business is being changed to an e-economy by new forces such as global competition, increased information availability, educated consumers, changing relationships, rapid innovations and increasingly complex products. In today's market, supply chain management has become key to competitive advantage. These days, Internet-based EMs are getting more and more popular. They emerge in industries supporting the exchange of goods and services of different kinds. The supply chain dimension of EMs is largely neglected and poorly managed while basic logistics operations are currently hampering turnover and revenues (Van Hoek, 2001). This chapter examines, based on a critical literature review, the connection of EMs and supply chain management. This chapter provides a survey and basic definitions of an EM and discusses the importance of EMs for supply chain management. The later part of the Chapter discusses the importance of agents in the supplier selection process and comparison of EM and supplier selection strategies. The comparison of approaches helps reach better understanding of the subject.

2.2 Electronic Marketplaces

Many EMs were established in late 1990's. The function of EMs is to facilitate the transaction between a buyer and supplier. Table 2.1 shows the various kinds of EMs developed since their inception. In Table 2.1, G stands for Government, B stands for Business and C stands for Customers. Internet-based EMs are getting more popular because the limiting factors of time and space seem to be overcome by the Internet. EMs are available 24 hours a day and they reduce the transaction cost and time drastically. Differences between B2B and B2C electronic commerce are summarized in Table 2.2.

Table 2.1 Various Electronic Marketplaces (Coppel, 2000)

G2G Example: Coordination	**G2B** Example: Information	**G2C** Example: Information
B2G Example: e-Bidding	**B2B** Example: e-markets (www.covisint.com)	**B2C** Example: e-commerce (www.amazon.com)
C2G Example: Tax Compliance	**C2B** Example: e-markets (www.priceline.com)	**C2C** Example: e-markets (www.eBay.com)

McCoy and Sarhan (1988) define EM, as "An EM separates the negotiating function from the physical transfer of the product or commodity in which the market trades. It can manage buyers' and suppliers' offers and bids, as well as moving products directly from suppliers to buyers. The system is open to all buyers and suppliers, regardless of their location and can provide instant market information to all traders." Bakos (1991) define EM, as "EM is an interorganisational information system that allows the participating buyers and suppliers to exchange information about prices and product offerings". Bradley and Peters (1997) say, "EM can be viewed as a public listing of products and their attributes from all suppliers in an industry and available to all potential buyers." In the process, they create economic value for buyers, suppliers, market intermediaries, and for society at large."

Segev et al., (1999) say, "Compared to many other electronic procurement solutions, electronic markets occupy a neutral position between buyers and sellers, providing services to both sides of a transaction. An electronic market represents a virtual place where buyers and sellers meet to exchange goods and services". According to Dai and Kauffman (2000), "EM functions as digital intermediaries that focus on industry verticals or specific business functions. They set up marketplaces where firms participate in buying and selling activities after they obtain membership." Mueller (2000) indicates "EMs allow buyers and suppliers to exchange information about product offerings and prices bid and asked." As per Ariba, (2000) "EMs are commerce sites on the public Internet that allow large communities of buyers and suppliers to "meet" and trade with each other.

Table 2.2 Comparison between B2B e-markets and B2C e-commerce (Complied from various sources, including Sculley and Woods (2001), and Morgan Stanley Dean Witter (2000))

Market characteristics	**B2B e-markets**	**B2C e-commerce**
Value/size of transactions	Very large value	Relatively small
Buyer-Seller Relationship	Usually long term, based on contracts	Mostly short-term and spot sales
Participants	Many participants interacting in a given transaction-Network of suppliers, partners and buyers	Many consumers dealing directly with single sellers (one supplier, many customers)
Functionality requirements	High degree of functionality required	Less functionality required
Pricing	Negotiated prices, long-term contracts, auctions, catalogue prices	Fixed prices, mainly catalogue
Payment system	Credit cards, bank credit, electronic account-to-account payments	Credit cards, electronic account-to account payments
Order fulfillment	Stringent requirements regarding availability of products and particulars of fulfillment, global express deliveries	Fulfillment requires more flexible and less stringent, global express deliveries
Infrastructure requirements	More complex, customized	Minimum requirement- a browser with Internet access
Entry conditions	Cost of technology and economies of scale may create entry barriers, especially for sellers	No major entry barriers
Network effects	Beneficial to both sellers and buyers	Beneficial to sellers and less to buyers
Intermediaries	Intermediaries are bypassed but also used in some cases	Intermediaries are bypassed
Product design	Custom-made according to specification	Standardized
Sales procedure	On-line catalogues, tender	On-line catalogues
Security	Network security and corporate privacy	Protection of consumer information and needs

They present ideal structures for commercial exchange, achieving new levels of market efficiency by tightening and automating the relationship between suppliers and buyers." As per Kaplan and Sawhney (2000) "EM is a meeting-point where suppliers and buyers can interact online. To summarize, primary role of an EM is to facilitate transaction between a buyer and supplier agent. It also facilitates transactions by assuming different roles like logistics service providers, banks and other intermediaries.

2.3 Types of Electronic Marketplace

Electronic Markets can be classified by the following characteristics:

(a) The more stakeholder-focused way divides EM into buyer-oriented, supplier-oriented and neutral;

(b) The most straightforward categorization is vertical and horizontal EM;

(c) Another possibility is to distinguish them as open and closed electronic markets.

2.3.1 Buyer-oriented, Supplier-oriented and Neutral Electronic Marketplaces

The role of a buyer-oriented marketplace is to aggregate buyers. Buyer-oriented marketplaces such as CommerceOne (www.commerceone.com) concentrate primarily on creating efficiencies for the buyers. Buyer-oriented networks generally have several objectives, such as to drive procurement costs down for the participating buyers, to reduce administration cost, to increase visibility and to facilitate global sourcing. All factors are aligned to increase benefits to buyers.

A supplier-oriented aggregated marketplace concentrates on bringing multiple suppliers together into a central catalogue and product information repository as for example Build-Online (www.buildonline.com) and e-steel (www.esteel.com). The key to a supplier-oriented marketplace is to provide multiple suppliers a forum to present their catalogues and conduct business with as many buyers as possible, in other words to aggregate contents that will meet buyers' needs.

Supplier-oriented marketplaces also have the ability to aggregate their suppliers, acting as a service provider, wrapping products and services together and offering them to buyer-oriented aggregated networks directly. All types of relationships are aligned to increase benefits to suppliers.

Neutral e-markets, driven by a third party for example CPGmarket (www.cpgmarket.com), Tribon (www.tribon.com) and ChemConnect (www.chemconnect.com) are the true markets because they are equally attractive to buyers and suppliers. However, these marketplaces often face the "chicken-and-egg" problem: buyers do not want to participate unless there are a sufficient number of suppliers and suppliers do not want to participate unless there are a sufficient number of buyers.

2.3.2 Vertical and Horizontal Electronic Marketplace

Fundamentally, there are two kinds of electronic markets -- vertical and horizontal electronic markets. Vertical electronic markets are industry specific. For example, ChemConnect (www.chemconnect.com), Chemdex (www.chemdex.com), OneChem (www.onechem.com), and e-Chemicals (www.echemicals.com) are for the chemical industry. Vertical EMs aggregate supply or demand in vertical industries. Vertical markets require a good deal of industry knowledge. Vertical markets optimize buyer-supplier relationships in a specific industry, such as chemicals, metals, energy and telecommunications.

Horizontal EMs facilitate the purchase and sale of goods and services used by a range of industries for example Asista (www.asista.com), Deutsche Telekom (www.telekom3.de), BizBuyer (www.bizbuyer.com) and Grainger (www.grainger.com). Horizontal marketplaces are also known as "functional marketplaces" because they cut across industries to concentrate on specific functions in an enterprise including human resources, procurement, logistics and marketing.

In addition, there are companies that provide vertical and horizontal EMs with a technical platform. They have become known, as Application Service Providers for examples TRADEX Technologies, The Sun/Netscape Alliances or Trading Dynamics. These companies offer tools such as information-publishing tools, catalogue software, transactional capabilities, payment services, or customer relationship management functionality.

2.3.3 Open or Closed Electronic Marketplaces

An open EM is open to all buyers and suppliers. By contrast a closed EM is open only to certain suppliers and buyers. EMs with long reach, that is, a relatively open structure allowing many participants, will have simple functionality. Agreeing on a highly complex functionality with many participants is simply too difficult to accomplish. EMs with short reach, that is, a relatively closed structure resulting in few participants, may have complex functionality. The detailed differences are depicted below in Table 2.3.

Table 2.3 Closed and Open Electronic Market

Closed EMs	Open EMs
B2B	Either B2B or B2C or C2B
Industry –Specific	Global
Limited number of participants	Unlimited number of participants
Known and connected participants	Known and unknown partners
Security through networking	Security and authenticity necessary
High degree of information sharing	Low degree of information sharing
High degree of collaboration	Low degree of collaboration

2.3.4 Types of Electronic Marketplace based on Operating Mechanisms

Electronic markets based on operating mechanisms can be distinguished as follows:

a) The more economic and price-focused classification divides EM into markets with fix or variable pricing mechanism.
b) EM can be classified with regards to the purchasing process.
c) EM can be classified with regards to the market mechanism.

2.3.4.1 Electronic Marketplace based on Pricing Mechanism

The pricing mechanism can also be used to categorize EMs (Kaplan and Sawhney, 1999). Online catalogues, for example, Papersite (www.papersite.com), Requisite Technology (www.requesttechnology.com) or Harbinger (www.harbinger.com) take the paper-based catalogues of multiple vendors, digitize the product information and provide buyers with one-stop shopping over Internet. The prices are fixed for online catalogues. An EM with auctions price mechanism, for example, USBid (www.usbid.com), Manheim Online (www.manhiem.com), GoCargo (www.gocargo.com) provides a venue for the purchase and sale of unique items such as surplus inventory, used capital equipment, discontinued goods, perishable items, or refurbished products. In a traditional auction, the competitive bidding process results in upward price movement (Klein 1997; Vigroso, 1999; Emiliani, 2000). The reverse English auction, for example, Economia (www.economia.com), ChemConnect (www.chemconnect.com), CPGmarket (www.cpgmarket.com), is a format in which suppliers compete for buyers offer to purchase resulting in a downward price movement.

2.3.4.2 Electronic Marketplace based on Purchasing Mechanism

This classification is based on "What and how" business purchases. "What businesses buy" can roughly be divided into manufacturing inputs and operating inputs. Manufacturing inputs are raw materials and components that go directly into a product or process whilst operating inputs, which are not part of the finished products, fall into the categories such as maintenance, repair and operating goods. Manufacturing inputs tend to be industry-specific whereas operating inputs require a higher degree of information sharing and collaboration (Kaplan and Sawhney, 2000).

The other classification based on purchasing mechanism is "how products and services are bought". Companies can either engage in systematic sourcing or spot sourcing. Systematic sourcing involves negotiated contracts with qualified suppliers. In spot sourcing, the buyer's goal is to buy a product at lowest possible cost and to speculate. Commodity trading for goods like oil, steel, and energy exemplifies approach.

Spot transactions rarely involve a long-term relationship with the buyer; in fact, buyers on the spot market often do not know who they are buying from.

2.3.4.3 Electronic Marketplaces based on Market Mechanisms

EMs can create value by two fundamentally different mechanisms: aggregation and matching (Segev and Beam, 1999; Bakos 1991, 1998). An EM that uses the aggregation mechanism brings together a large number of buyers and suppliers under one virtual roof. They reduce the transaction cost by providing one-stop shopping. The aggregation mechanism is static in nature because prices are pre-negotiated and an important characteristic of this mechanism is that adding another supplier benefits buyers, and adding another buyer benefits suppliers.

Unlike the static aggregation mechanism, the matching mechanism brings buyers and suppliers together to negotiate prices on a dynamic and real-time basis therefore, the matching mechanism leads to more transactional relationships and adding any new member benefits both buyers and suppliers. This makes matching a more powerful mechanism than aggregation. At the same time, however, the matching mechanism is far more complex.

2.4 Supply Chain Management and Electronic Marketplaces

2.4.1 Relationships from a Theoretical Stand Point

Theoretically, the relationship between EMs and supply chain management appears problematic. Co-operative supply chains aim to reduce the number of suppliers and form long-term strategic relationships that remove competition. EMs promote competition and allow buyers to search for suitable suppliers and support transaction-based relationships.

Economies have two basic mechanisms for coordinating the flow of materials or services through adjacent steps in the value chain—markets and hierarchies (Malone et al., 1987). Williamson (1981) categorizes transactions into those that support co-ordination between multiple buyers and suppliers, that is, market transactions, and those that support co-ordination within the firm, as well as the industry value chain like hierarchy transactions.

Williamson (1981) points out that the choice of transaction will depend on a number of factors, including the parties' interest in the transaction, and ambiguity and uncertainty in precisely describing the transaction. The EMs hypothesis developed by Malone et al, (1987) predicts that, all other things being equal, the introduction of information technology will lead to greater use of markets rather than hierarchies for economic transactions.

Another premise is the move-to-the-middle hypothesis developed by Clemons et al., (1993). The hypothesis posits the possibility of using EM as an intermediate body for transactions between supplier and buyer. The question of whether supply chain management and EMs are compatible, is in fact the question whether EMs are moving to hybrid forms within the market-hierarchy continuum (Williamson, 1981) as it was predicted by the move-to-the-middle hypothesis (Clemons et al., 1993).

2.4.2 Relationships from Practical Stand Point

From a practical standpoint, supply chain management and EMs are compatible. Crowley (1998) says that today every business competes in two markets: the marketplace, in which resources and products exist physically and the marketspace, which is a virtual world of electronic commerce in which the main object of transaction is information. Managing these two interacting value-adding processes, in the two mutually dependent realms, is seen as posing new conceptual and tactical challenges for every firm. Graham and Hardaker (2000) argue that the marketplace is part of the web-based relationships in the supply chain that could be divided into three company perspectives, namely business-to business, business-to-consumer and marketspace.

But the question is whether Internet transactions and physical logistics are conflicting or complementary. Gural et al. (2001) argue that Internet commerce does not eliminate the need of physical logistics systems; in fact, it even increases their importance. The flow of information between the supply chain partners can be efficiently managed over the Internet reducing the costs and increasing the speed and the quality of data transfer. On the other hand, the EM should organize a complementary physical logistics system in order to distribute material products to its clients. But so far this is done inadequately.

Van Hoek (2001) claims that the supply chain dimension of e-business is largely neglected and poorly managed, while the mal-performance of logistics is currently hampering turnover and revenues of e-commerce applications in a severe way. Furthermore, Gural et al, (2001) emphasizes that EMs can subcontract the functions of the physical logistics system to other firms. It can be said that the implementation of the Internet is changing the structure of the classical distribution channel, encouraging an increased specialization of the physical delivery functions. Benjamin and Wigand (1995), on the other hand, develop a model that contains stakeholders in the value chain, which are connected to the national information superhighway. This ''highway'' encloses transportation of both physical goods and information and connects producers of information, producers of physical goods, electronic retailers (e-retailers), EMs, physical distribution networks, and electronic channels.

Emiliani (2000), Gudmundsson and Walczuck (1999) bring insights of supply chain management to specific kinds of EMs. Emiliani (2000) argues that an on-line auction is an attractive technological solution for reducing costs, but it does not help uncover the root causes of poor cost management within the buying firm. Further, the intermediaries understand commodity management, markets, and information technology very well, but do not understand supply chain management and lean production, as evidenced by contract terms and conditions. As a result, Emiliani (2000) proposes that online auctions will delay the adoption of modern supply chain management methods and the implementation of lean production that are needed by both buyers and suppliers in order to truly eliminate waste and reduce total costs.

2.4.3 Internet Enabled Business Relationships

In the following section, the relevancy of EMs for supply chain management is analyzed. While there are myriad aspects within a relationship among trading partners in an EM, three broad categories have been identified: transactional, information-sharing, and collaborative relationships. The suggestion is that merely transactional-oriented EMs depends to a lower degree on supply chain management than collaborative-oriented EMs.

Transactions within a buyer–supplier relationship involve the activities carried out to execute the buyer's purchase of a commodity. These activities involve information notifying the buyer and supplier that a purchase is taking place and that funds need to be exchanged. Historically, EMs have mostly dealt with the transactional aspects of a relationship, thus automation has focused on sending purchase orders and invoices and on transferring funds. The only information that must be transmitted in this type of relationship is that needed to execute a purchase. The next trading relationship involves information sharing or data exchange. This involves at least one of the following arrangements (Noekkenved, 2000):

(a) The partners are given access to a system that has the shared information in it

(b) One partner transmits shared information to the other partner. For example, Web-based catalogues allow buyers to electronically view product information. Buyer or supplier can share various types of information--- either before or after a purchase is made.

This information may involve the supplier's offerings or the buyer's future needs. Historically, little information has been electronically shared among trading partners. The recipient is using the data as-is and is not providing feedback (one-directional information flow); on the other hand information-sharing does little to reduce the uncertainty faced by trading partners in determining future demand, and does not grant the opportunity for the other partner to provide his or her own insight and knowledge of customer needs or other market opportunities. In addition, there is little opportunity to work together on matching supply with anticipated customer demand. To further enhance a buyer–supplier relationship some progressive companies are moving towards collaborative relationships, in which they are ''working jointly with others, especially in an intellectual endeavor'' (Noekkenved, 2000). Collaborative efforts enable trading partners to work together to better understand future demand and to put plans in place to satisfy it profitably. In a collaborative relationship, information is not just exchanged and transmitted but is also jointly developed by the buyer together with the seller. For example, in the case of working collaboratively on customer requirements, trading partners might collaborate on new product designs and customer demand forecasts. Generally, this information deals with future product plans and needs hence, it can be seen that supply chain management and electronic markets are linked together.

2.5 Agent Technologies in Electronic Marketplaces

2.5.1 Transaction Phases

EMs facilitate exchange of goods, information, services, and payments associated with supply chain management (Bakos, 1998). Four phases of such transactions can be distinguished as information, negotiation, settlement and after-sales. In the information phase, buyers identify and evaluate their needs and possible sources to fulfill them and at the same time, suppliers arrange for providing their goods and identifying potential customers. To a large extent, these steps evolve around exchange of information. The information phase ends for a market participant with the submission of an offer. With the receipt of an offer, the second phase starts, that is the negotiation phase. Potential buyers and suppliers negotiate the terms of the intended transaction by jointly identifying possible solutions with the goal of reaching a consensus. The result is a legal-binding contract, representing the agreement between the market partners. In the settlement phase, the agreed-upon terms of the contract are fulfilled. Depending on the type of the exchanged goods or services as well as the participating partners, the settlement phase can be an initiator of secondary market transactions (e.g., logistics and financial services). Result of this phase is the fulfillment of the contract. There is a fourth phase, namely after-sales and this includes after-sales product support, customer service and the evaluation of the transaction's outcome.

2.5.2 Agents Technologies in Various Phases

As defined in Chapter 1, agents are computer systems that are capable of performing some flexible, autonomous actions in order to meet its objectives (Jennings et al., 2001). The various phases of the procurement can be automated through various agent technologies. There exist various kinds of agents such as mobile agents, goal oriented agents and communicative agents (Clements et al., 1997). Various authors have used multiagent approaches to illustrate the importance of agents in automating the supply chains (Swaminathan et al., 1998). The multiagents are applied to various departments of the firm.

The multiagent approach for the modeling and analysis of supply chains indicates that a supply chain consists of structural elements and control elements. Structural elements consist of retailers; distribution centers; manufactures etc and control elements consist of components - related information, demand and supply flow. This element helps in modeling supply chain dynamics. On other hand, autonomous agents are capable of working on their own (Zeng and Sycara, 1999). These agents are connected with each other via the Internet. Chirstor Carlson (2002) has given due importance to the automation of the negotiations in the EMs.

The various approaches employed for automating the procurement process includes the game theoretic approaches, argument based approaches, heuristics approaches and various artificial intelligence algorithms (Jennings et al., 2001). Heuristics approaches are used to automate the process by classifying attributes as non-negotiable and negotiable. Jennings et al., (2001) have implemented various agents in the negotiation process such as price agents, rating agents, search agents, signaling agents etc. The use of agents helps a lot in utilizing real-time information from the web hence maintaining market transparency. The same concepts have been utilized in British Telecom (Faratin et al., 1998) with the only difference being the use of autonomous agents. The process involves six agents and the agents are concerned with various departments. Game theory models may be utilized in two ways for negotiation problems (Jennings et al., 2001). The first way is for the design of appropriate protocols. The protocol defines the rules of encounter. The second way is to design a particular strategy that individual agents may use while negotiating (Rosenschien and Zlotkin, 1994). An agent will aim to use a strategy that maximizes its own individual welfare.

Jennings et al., (2001) suggested that heuristics take into account computation and decision-making abilities. However heuristics produces good, not optimal solutions. A combination of heuristics and multi-attribute utility theory reduces the search space and provides effective results (Bui et al., 2001). The number of negotiation objects may be increased. Those attributes, which are negotiable, should be given preference. However, heuristics approaches provide sub-optimal solutions and sometimes it needs extensive evaluation. In argumentation-based approaches, agents argue in order to clarify the proposals stating the reasons for acceptance or rejection. The basic idea is to incorporate more information so that agents may clarify rejection or acceptance (Jennings et al., 2001).

A genetic algorithm may carry out the negotiation process. The agent first sets up the population of chromosomes, each of which represents the candidate's offer of the current round of negotiation, and various mutation and mating methods are employed till satisfactory offspring are generated (Choi et al., 2001). Many researchers have developed fuzzy logic systems to have some outputs, for example, the simulation engine designed by Wasfy and Hosni (1998) called NEGOTIATE. This simulation engine runs on mamdani fuzzy logic systems. It uses the trapezoidal membership function and certain parameters as inputs.

2.6 Comparison of Approaches Towards Design of EMs

This section compares the various approaches towards the design of EMs. Kia et al., (2002) state, "Electronic commerce is a popular domain of agent technologies. Agents support the buying and selling of products and services for the users." Kia et al., (2002) have implemented a three-layer agent architecture aKIA to demonstrate their approach. Ben-Ameur et al., (2002) discusses an agent-based approach for e-procurement. The agent-based approach is well equipped to address the challenges of e-procurement. Ben-Ameur et al., (2002) suggest the shared information space for negotiation exchanges and states.

Lang and Whinston (1999) examine the design of decision support system (DSS) for EMs. Lang and Whinston (1999) state "DSS intermediary provides a bridge between the two groups and attempts to make a profit based on operations since the intermediary will select the best software technology where it can be found and look at the geographically distributed, potentially world-wide, base of customers." The electronic storefront provides information about the services available by the decision support system. Lang and Whinston (1999) suggest the intensive use of software technology for the design of intermediaries such as CORBA in combination with electronic markets. Many authors like Jennings et al., (2001) Ben-Ameur et al., (2002) suggest an agent-based approach for negotiations in EMs, but have not explained the actual design of EMs.

Most of the major consulting firms have designed their own websites offering products and services. For example, the renowned consulting firm, Ernest and Young International, has developed a well-crafted on-line system called Ernie (http://www.eyi.com) that has a web interface and allows interested parties to browse through a collection of illustrative case demonstrations including DSS applications. Covisint (www.covisint.com) is a well-crafted example of B2B marketplace for automobile manufacturers that has a web interface and provides quality services for procurement. The participants of Covisint have their electronic procurement interfaced in the website. Many EMs such as amazon.com (www.amozon.com), deal with small products such as daily needs, books, calculators etc. however these are business-to-customer marketplaces where customers receives advertising about the products through email.

Davidrajuh (2003) suggests a methodology of automation of supplier selection as an e-commerce initiative. Davidrajuh (2003) suggested a multiagent model of partner selection with three stages -- bidder selection, partner selection, and performance evaluation. Vokukra et al., (1996) discuss a prototype expert system for supplier evaluation and selection. It is noticeable that the design of the expert system includes many aspects of the procurement process. Kersten (2002) describes the various aspects of electronic negotiation. The work reviews the field of negotiation. Bichler et al., (2001) details the ABSolute framework providing buyer-side decision support for electronic sourcing. The framework is based on the WORA technique (Weight Assessment by Ordinal Ranking of Attributes).

2.7 Comparisons of Approaches for Supplier Selection

This section compares some of the existing supplier selection techniques. The comparisons enable a better understanding of the decision –making methodologies in the process. There are many approaches that exist in the literature to evaluate suppliers.

In the total cost approach, the quoted price of a supplier is considered as the starting point and then selection criteria is evaluated in terms of cost factors. The approach converts the different factors important for the success of the firm into a cost component and each cost component is added to the quoted price of the supplier. The supplier with the lowest total cost is preferred. The biggest drawback of this approach is that it never considers the non-monetary issues or factors whose cost component cannot be calculated.

Multiple attribute utility theory (MAUT) is helpful in purchasing scenarios where supplier selection criteria are multiple and conflicting. The approach is most suited for international supplier selection process. The definition of utility function determines the efficiency of the decision-making process. It should be noted that this kind of approach is suited for complicated supplier selection process. Multi-objective programming is used with Just-in-Time technologies. It is not practical to implement and are very complex in many cases.

The analytic hierarchy process is preferred as it includes many intangible factors for evaluation as compared to just the cost factor in the total cost of ownership approach. Bard (1992), Belton (1986) and Kamenetzky (1982) have done a detailed comparison of the analytic hierarchy process and multiple attribute utility theory. Their discussions suggest that AHP is preferred to MAUT for the linear utility function.

Yousef et al., (1996) discuss supplier selection in an advanced manufacturing environment. They describe existing models for supplier selection like categorical models, matrix and cost-based models etc. Their approach considers the inventory cost, demand and supply chain and the evaluation of suppliers. Murilidharan et al., (2001) suggest the confidence interval approach for supplier selection.

After the detailed comparison and study of the literature, it was decided to use AHP as the decision-making tool for the proposed supplier selection approach. It is an excellent approach that can be used in a multifactor decision-making environment and especially when subjective or intuitive consideration has to be incorporated. AHP provides a structured approach for determining the scores and a weight of the multiple criteria used and standardizes them so that they can be compared and decisions made.

Chapter 3 Design of an Agent-Mediated Internet based Business-to-Business Electronic Marketplace for Procurement

3.1 Introduction

Electronic commerce has significantly impacted the way businesses operate. It has also shown a wide impact on supply chain management especially procurement. Since the advent of electronic commerce, EMs have affected the procurement process. This Internet-based procurement process is called electronic procurement or e-procurement. The EM facilitates the flow of information and hence speeds up transactions. An agent-mediated Internet-based business-to-business EM for procurement is proposed.

The proposed EM is classified as a neutral, horizontal, and closed EM as it is equally attractive to both buyers and suppliers and open to different range of industries. The proposed EM consists of various components and user interface. The components of the proposed EM consist of buyers' agents, suppliers' agents, the message engine, decision engine, knowledge base and storage of transactions. The user interface (buyer or supplier) consists of help center, resource center, catalogues, search engine, trading partners, payment modes, language sections and transaction box. The schematic diagram of the proposed EM is depicted in Figure 3.1. Section 3.2 gives an overview of the design and Section 3.3 describes the components of the proposed EM in detail. Section 3.4 presents an architecture of the user interface for the proposed EM. Section 3.5 compares the proposed design with the existing approaches.

3.2 Overview of the Proposed Electronic Marketplace

The buyers identify and evaluate their purchasing needs and put forward the requests for proposals (RFPs) with the help of their agents. At the same time, the suppliers and their agents search the marketplace and identify potential customers. The users (buyers or suppliers) and their agents communicate through the message engine. The message engine consists of the communication and coordination modules that are equipped with the communication and coordination agent.

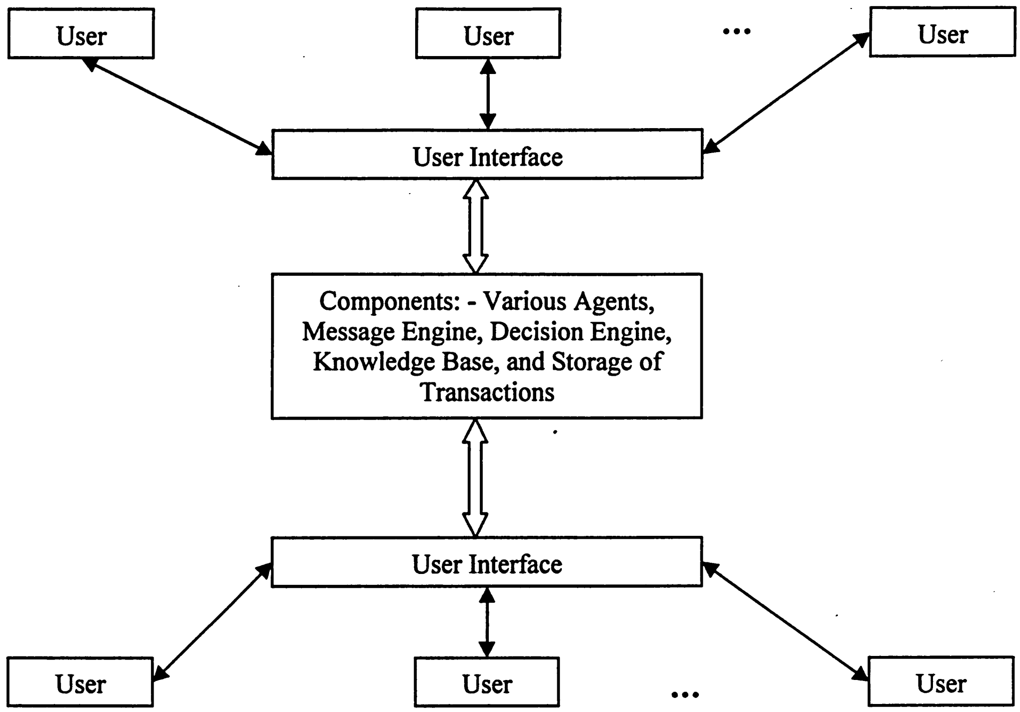


Figure 3.1 The Proposed Electronic Marketplace

The negotiation phase and the supplier selection phase are completed by the decision engine, which consists of the negotiation support module and the proposal evaluation engine. The negotiation support module discusses the negotiation strategy for the buyer and supplier agent to reach an agreement on deals (Rosenschien and Zlotkin, 1994). The proposal evaluation engine evaluates the responses to RFPs by the help of the software agent SupplySelect. The aim of SupplySelect is to select the best supplier for a given set of attributes and the parts to be purchased. SupplySelect utilizes a graphical user interface constructed on MS-Access. In the last phase, agreed-upon deals are fulfilled.

The knowledge base and storage of transactions act as information centers for the users and their agents. The knowledge base of the system is the database that stores information necessary to complete the procurement process. It is connected to the Internet and hence provides real time information. The transactions are stored in storage for transactions, the latter acting as a storage device of the EM. The knowledge base and storage of transactions are equipped with knowledge and storage agents.

3.3 Components of the Proposed Electronic Marketplace

The approach used in this thesis is to utilize the multiagent system and EM to facilitate the procurement process. The proposed design is well suited for business-to-business transactions in EMs. The components of the EM are depicted in Figure 3.2. The two directional arrows indicate communication; single directional arrows indicate sub-component, and straight line indicates agent. The users are buyers and suppliers. In this approach, it is assumed that a buyer initiates the procurement process by putting forward RFPs. The components of the proposed EM consist of buyers' agents, suppliers' agents, the message engine, decision engine, knowledge base, and storage of transactions.

The message engine transmits messages between various components of the EM. It initiates the procurement process by transmitting a message from a buyer to its agent. It consists of two modules, communication and coordination modules. The modules act according to communication and coordination protocols. The communication and coordination modules are equipped with their respective communication and coordination agents to automate the process. Each agent in the proposed EM is defined in its task-oriented domain.

The decision engine is an important part of the proposed framework. It consists of a negotiation support module and a proposal evaluation engine. The negotiation support module defines the negotiation process and strategy for negotiations between the buyer and supplier agents (Rosenschien and Zlotkin, 1994). The proposal evaluation engine selects the best supplier. Supplier selection is a multiple criteria decision-making process. The basic methodology used is an amalgamation of the additive value function and AHP (Hobbs and Meier, 2000). The supplier with the maximum total score is selected. It also ranks each supplier with respect to attributes. A software agent, called SupplySelect, is implemented in the decision engine to aid the buyer in the multiple criteria decision-making process of selecting the best supplier. SupplySelect utilizes a graphical user interface based on MS-Access.

The knowledge base is a database, which stores the information necessary for the procurement process. Since an EM is connected to the World Wide Web, the knowledge base is automatically linked with the Internet. It is an information resource center for the registered users providing real time information.

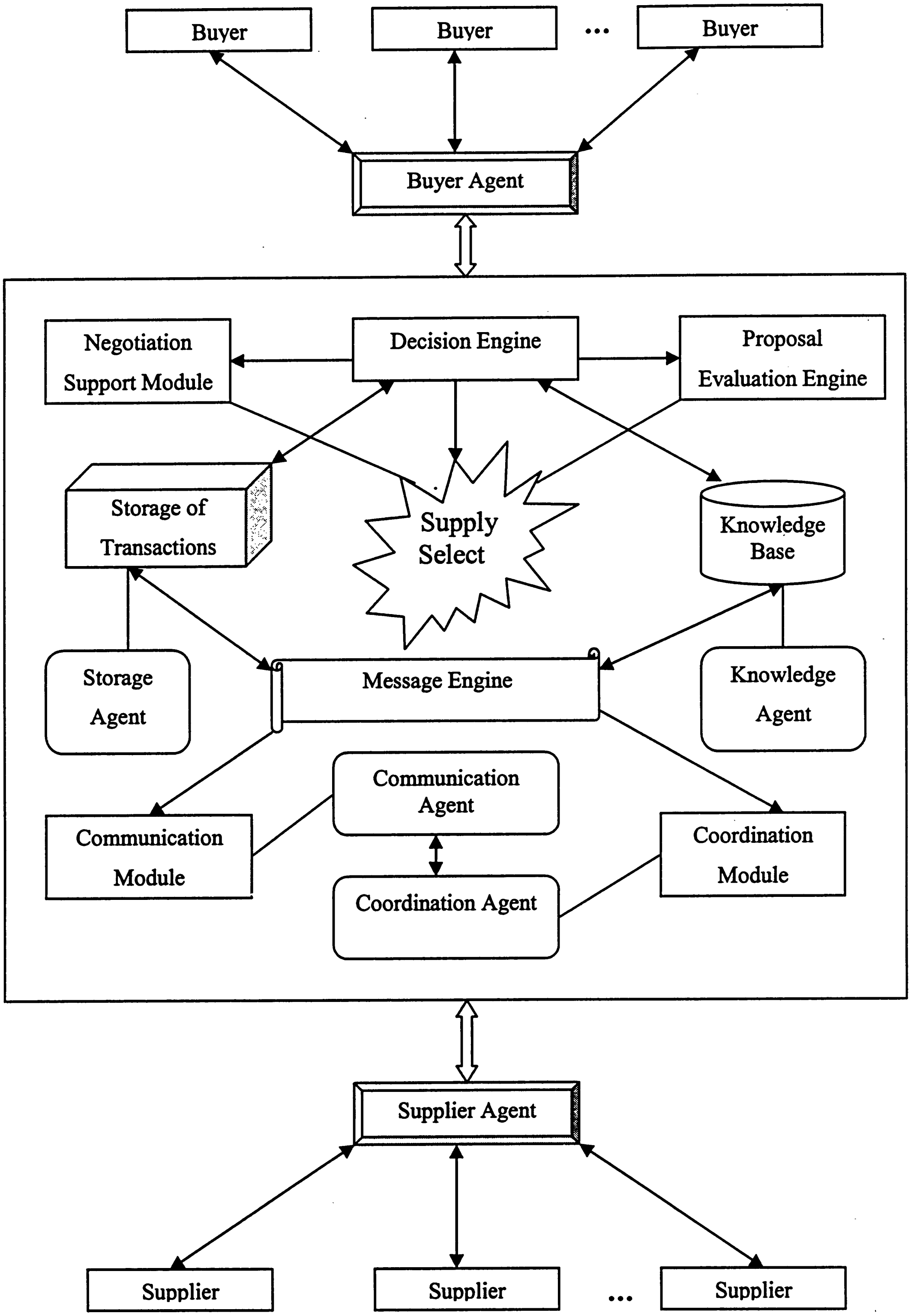


Figure 3.2 Components of the Proposed Electronic Marketplace

The agent in the knowledge base sorts out database queries. The knowledge base understands the needs of users and updates the information accordingly. "Storage of Transactions" stores the transactions of the users, buyers or suppliers, and their agents for future reference. It aids the buyer in the selection process. The buyer needs the history of transactions of each supplier with which buyer has interacted for the procurement process. Similarly, a supplier may access the history of transactions it has participated to maximize its profits. The storage is particularly helpful for evaluation of registered users and is different from the knowledge base in that the latter stores real time information whilst storage contains past transactions. However, the agent in "Storage of Transaction" also performs database queries in its task-oriented domain similar to the knowledge agent. The components work together to bring the end result of the selection of supplier and execution of agreements on a deal by users.

3.3.1 Users and Agents

In the proposed approach, EMs are open both to buyers and suppliers. Suppliers and buyers register in the EM by filling up the registration forms. In this approach, a neutral EM with buyer-side decision support is designed. The definition of users – buyers and suppliers, is the same for the entire EM. The buyers and suppliers may exchange their positions for particular transactions. The buyer may act as a supplier for certain parts to bigger manufacturers. Each user has its agent that automates the transaction process. The buyer and supplier agents are connected to an EM and hence they act as a bridge between the users and the EM. The task-oriented domains are designed for the agents in the proposed EM due to their task-oriented nature.

3.3.1.1 Buyer and Buyer's Agent

Buyers based on their needs purchase parts or products from the suppliers. A buyer initiates the process by contacting its agent that is connected to the EM. Agents communicate by transmission of messages. The task of the buyer agent is to transmit messages between the buyer and EM. The buyer agent's task oriented domain is denoted as $(TOD)_b$ and defined as a tuple of three parameters as shown below (Rosenschien and Zlotkin , 1994):

$$(TOD)_b = Tuple\ (T_b, A_b, C_b)$$

Where,

a) T_b is the task set of the buyer agent that includes transmission of messages between the buyer and EM. There is no limit to the number of messages that can be transmitted between the buyer and its agent.

b) A_b denotes the identification of the buyer agent.

c) C_b is a monotonic cost function. C_b: $[2^{T_b}] \rightarrow R^+$. $[2^{T_b}]$ stands for all finite subsets of T_b and R^+ denotes the set of positive real numbers. For any finite task set $X_b \subseteq T_b$, $C_b (X_b)$ is the cost of executing all tasks X_b by the buyer agent. In this case, cost function C_b is the length of time to deliver a message from the buyer to EM or viceversa. C_b is monotonic because if $Y_b \subseteq X_b$ and $X_b \subseteq T_b$ then $C_b (Y_b) \leq C_b (X_b)$. For example, if X_b is transmission of messages for a purchase of particular set of parts and Y_b is transmission of messages for a particular part in that set, then $Y_b \subseteq X_b$.

d) $C_b (\phi) = 0$ where, ϕ denotes the null task set i.e., the set without tasks.

The task-oriented domain of a buyer agent is also known as a delivery domain as it helps the buyer agent perform the delivery or transmission of messages between the buyer and its agent.

3.3.1.2 Supplier and Supplier's Agent

Suppliers respond to RFPs sent out by buyers by transmitting messages through the message engine. Suppliers put forward quotes for attributes such as price, quality, quantity and service that answer the buyer's requests. The supplier's agent automates the transaction process as it is connected to the EM. The task of the supplier agent is to transmit messages between the supplier and EM. The task-oriented domain for the supplier agent is denoted as $(TOD)_s$ and defined as shown below (Rosenschien and Zlotkin , 1994). The task-oriented domain for the supplier agent is a tuple of three parameters namely the task set, agent's identification and a cost function.

$$(TOD)_s = Tuple\ (T_s, A_s, C_s)$$

Where,

a) T_s is the task set of the supplier agent that includes transmission of messages between the supplier and EM. There is no limit to messages that can be transmitted between the supplier and its agent.
b) A_s denotes the supplier agent.
c) C_s is monotonic cost function such that C_s: $[2^{T_s}] \rightarrow R^+$. $[2^{T_s}]$ stands for all finite subsets of T_s and R^+ denotes the set of positive real numbers. For any finite task set $X_s \subseteq T_s$, $C_s\ (X_s)$ is the cost of executing all tasks X_s by the supplier agent. The definition of monotonic cost function holds good for supplier also. It is the length of time the agent needs to pass on the message between the supplier and EM.
d) $C_s\ (\phi) = 0$ where ϕ denotes the null task set for a supplier agent.

The task-oriented domain for the supplier agent is also known as a delivery domain as the agent is responsible for the delivery of messages from one point to another (Rosenschien and Zlotkin, 1994).

3.3.1.3 Efficiency Functions of Buyer and Supplier Agent

The efficiency function of the buyer and supplier agent is inversely proportional to the absolute value of relative error between the desired output and actual output of the subsystem to which the agent is committed in a certain period of time. It is denoted as E_b and E_s, and is defined as below.

$$E_b = \frac{1}{1+\left|\frac{O_{db}-O_{ab}}{O_{db}}\right|} \text{ and } E_s = \frac{1}{1+\left|\frac{O_{ds}-O_{as}}{O_{ds}}\right|}$$

Where,

a) O_{db} is the desired output of the buyer agent

b) O_{ds} is the desired output of the supplier agent

c) O_{ab} and O_{as} is the actual output of the buyer and supplier agent

If O_{as} or O_{ab} = O_{ds} or O_{db} within a certain period of time, then E_b or $E_s = 1$, otherwise efficiency functions take a value of between 0 and 1. There is a time constraint, τ, associated with tasks and an agent should be able to complete the tasks within τ. This is the commitment of an agent. The more the agent fulfills its commitment the more efficiency it gains. When a buyer or supplier agent completes its tasks within τ, it gains maximum efficiency.

The error (O_{ds} or O_{db} – O_{as} or O_{ab}) at the end of period τ quantitatively indicates the degree to which a task has been completed, or equivalently, the extent to which an agent fulfills its commitment. If the system is still far away from its desired state at the end of τ, the error is large, which means commitment of the agent is poor. On the other hand, if the system is very close to its desired output, the error will be very small, which shows that the agent fulfills its commitment very well. For the buyer and supplier agents, the desired output is the state where both of them settle on an agreement in a particular transaction. The efficiency function keeps checking on the functionality of the agents and helps analyzing the efficiency of the proposed design.

3.3.2 Message Engine

The message engine transmits messages between the components of the EM. It consists of two modules, communication and coordination modules. In the proposed design of the EM, a buyer specifies its purchasing needs by generating a message. The communication module generates the messages and the coordination module controls the flow of messages. The detailed structure of the message engine is shown in Figure 3.3. The communication and coordination modules interact with each other during the transmission of messages. The modules are equipped with communication and coordination agents respectively. The rules of message transactions, also known as protocols, are defined in the succeeding sections. The messages are generated according to a generalized format to structure the transmission process. A user may or may not use all the fields of the message for a transaction. A structured transaction is easy to store and access from the storage device i.e. "Storage of transactions".

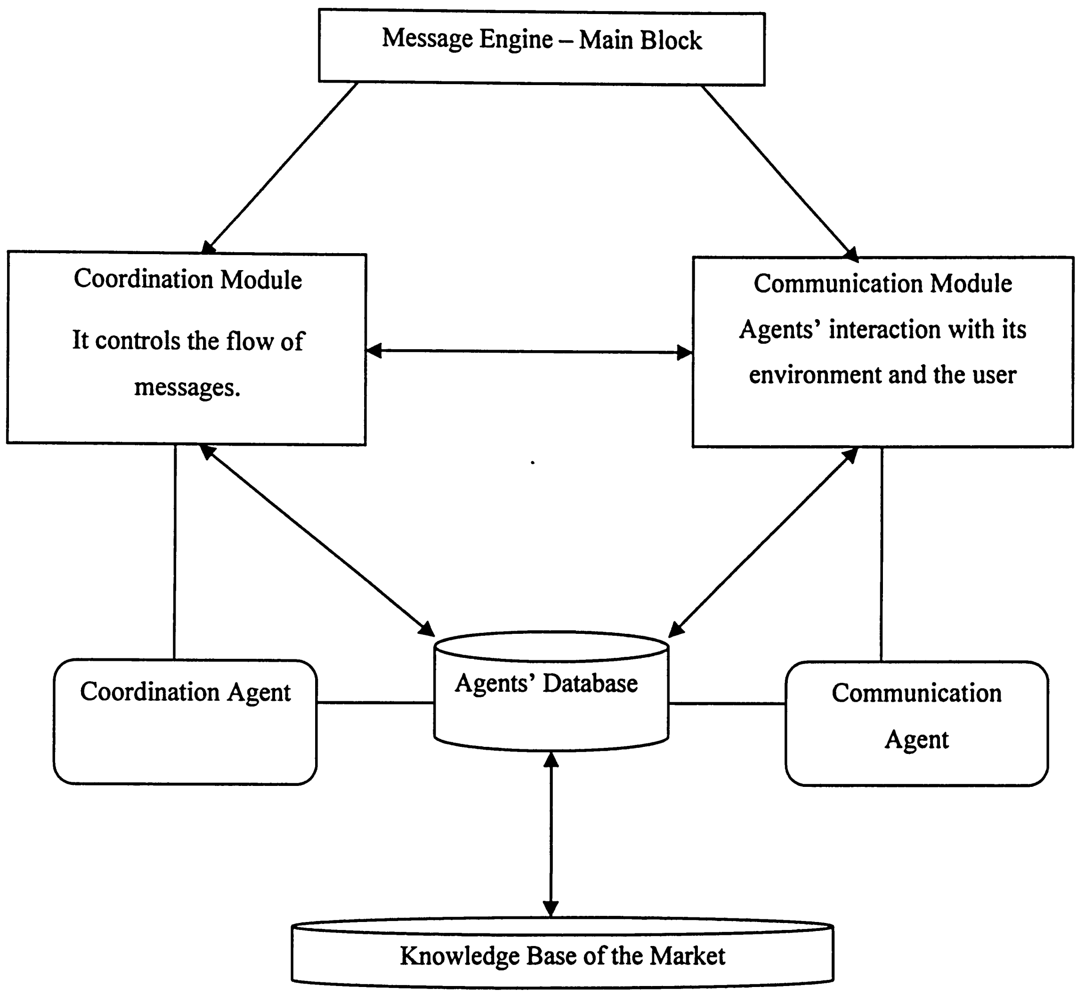


Figure 3.3 Structure of the Message Engine

3.3.2.1 Generalized Format of a Message

The generalized format of a message is depicted in Table 3.1. It is observed that the message gives detailed information about the user. The format is comparable to RFPs by the buyer. The users can analyze the purchasing trend by viewing the entries in the message box. The latter consists of following fields:

a) Buyer's name – It reflects the buyer's name registered in the EM.

b) Buyer's identification code – This code is assigned to the buyer after registration in the marketplace.

c) Supplier's name – It reflects the supplier's name registered in the EM.

d) Supplier's identification code – This code is assigned to the supplier once he or she registers in the marketplace.

e) Message-Code – This code identifies the message for a particular transaction. The code is critical when a message is retrieved for future reference from the storage of transactions.

f) Part-to-be-purchased – This field identifies the part and its code from the knowledge base of the marketplace.

g) Price Specifications – It specifies the price quotes by the user.

h) Quantity Specifications – It specifies the quantity of parts or products.

i) Quality Specifications – This field specifies the quality of parts or products.

j) Service specifications – It gives information about the delivery time and payment modes.

k) Suppliers' Performance – It tells about the suppliers' past performance. This is significant for proposal evaluation.

l) Counter proposals – This field consists of counter specifications for the attributes like price/quality/quality and service. Counter proposals are particularly important for the conclusion of an agreement on deals.

m) Constraints – This field consists of constraints on the attributes. For example, if the user is interested in customized products or products with special features, the user may define the constraints in this field.

n) Comments – Any remarks related to parts, attributes or special remarks are given in this field.

For example, if Ford Motor Company wants to purchase a gear then the first message written by Ford Motor procurement department should take the form as shown in Table 3.2. The buyer, Ford Motor, forwards its RFPs that state the specifications based on needs of the company. One of suppliers, Chalmers Suspension International Inc., will send its quote for the corresponding attributes. Once the quotes from the different suppliers are analyzed, the buyer, Ford, will select the best supplier.

Table 3.1 Format of a Message

Buyer's Name	*Registered Name of the Buyer*
Buyer's ID	*Buyer's Identification Code*
Supplier's Name	*Registered Name of the Supplier*
Supplier's ID	*Supplier's Identification Code*
Message-Code	*Message Identification Code*
Part-to-be-purchased	*Name and Code of Part or Product to be Purchased*
Price-Specifications	*Price Specification from User*
Quantity-Specifications	*Quantity Specifications from User*
Quality-Specifications	*Quality Specifications from User*
Service-Specifications	*Specification Related to Delivery and Mode of Payments*
Suppliers' Performance	*Information about Suppliers Past Performance*
Counter-Proposals	*Counter specifications on attributes*
Constraints	*Constraints related to any attributes*
Comments	*Any Remarks*

Table 3.2 Example of a Message

Buyer's Name	*Ford Motor*
Buyer's ID	*001*
Supplier's Name	*Not Available*
Supplier's ID	*Not Available*
Message-Code	*M-01, Tuesday, July 1, 2003, 11:46 AM*
Part-to-be-purchased	*Gear, 27*
Price-Specifications	*$10,000 By Ford Motor*
Quantity-Specifications	*250 By Ford Motor*
Quality-Specifications	*Quality Rating - A*
Service-Specifications	*Time of Delivery – July 10, 2003 and With First Payment*
Suppliers' Performance	*Not Available*
Counter-Proposals	*Not Available*
Constraints/Comments	*Not Specified*

3.3.2.2 Communication Module

As the name indicates, the communication module helps agents in communicating and consists of internal and external receivers. It receives and sends messages and interacts with the coordination module. An internal receiver transforms the internally queued messages to a communication agent and stores it to the outgoing message queue. An external receiver transforms each external message to an internal one and adds it to the queue of incoming messages. The message transmitter monitors each message sending the queued messages to the coordination module via the communication agent. The agent in the module works according to the communication protocol.

Communication Agent

The main task of the communication agent is to communicate between the various components of the EM and it acts according to the communication protocol. There is no limit to the amount of messages that are transmitted through the communication agent. The "Postmen and Delivery" task-oriented domain for the communication agent is defined as a tuple shown below.

$$(PD)_{cm} = Tuple\ (T_{cm}, A_{cm}, C_{cm})$$

Where,

a) $(PD)_{cm}$ denotes the postmen and delivery domain of the communication agent.
b) T_{cm} is the task set for the communication agent.
c) A_{cm} is the identification of the communication agent.
d) C_{cm} is a monotonic cost function for the communication agent. $C_{cm}: [2^{T_{cm}}] \rightarrow R^+$. $[2^{T_{cm}}]$ stands for all finite sets of T_{cm} and R^+ is the set of positive real numbers. The monotonic cost function denotes the length of time needed by an agent to deliver messages between the various components of the system.
e) $C_{cm}(\phi) = 0$ here ϕ stands for the empty task set of the communication agent.

The task-oriented domain for a communication agent is known as "Postman and Delivery" domain as it resembles the task of a postman. A postman delivers letters to different destinations from the starting point, the postal center (Rosenschien and Zlotkin, 1994). The communication agent delivers the messages between various components of the EM. The communication agent transfers the outgoing messages to various components and receives the incoming messages for processing.

Communication Protocol

The components of the proposed marketplace interact by sending messages between themselves. Each message has got a particular task associated with it and helps in the purchase procedure. Each time an agent receives a message from another agent, it responds to the message by taking further actions. Each message type governs a specific interaction between the various participants of the EM.

The communications between the participants of the system may be divided into: agent-agent communication (e.g., communication between the buyer and supplier agents); agent-user communication (e.g., communication between the buyer and its agent); and user-user communication (e.g., communication between the supplier and buyer after negotiation). These forms of communication are depicted in Figure 3.4.

Communication Messages

The messages are the important means of communication between the users. It is by the means of messages the agents or users arrive at agreements on deals or selection of best suppliers. Three types of messages are involved in transactions: the specification messages; the messages for RFPs; and the messages for responses to RFPs.

As the name implies, the specification message specifies the parts or products to be purchased and their associated features and criteria. The specification message occurs between the user and its agent. The message for request for proposals and the message for responses to proposals are included to indicate message flow.

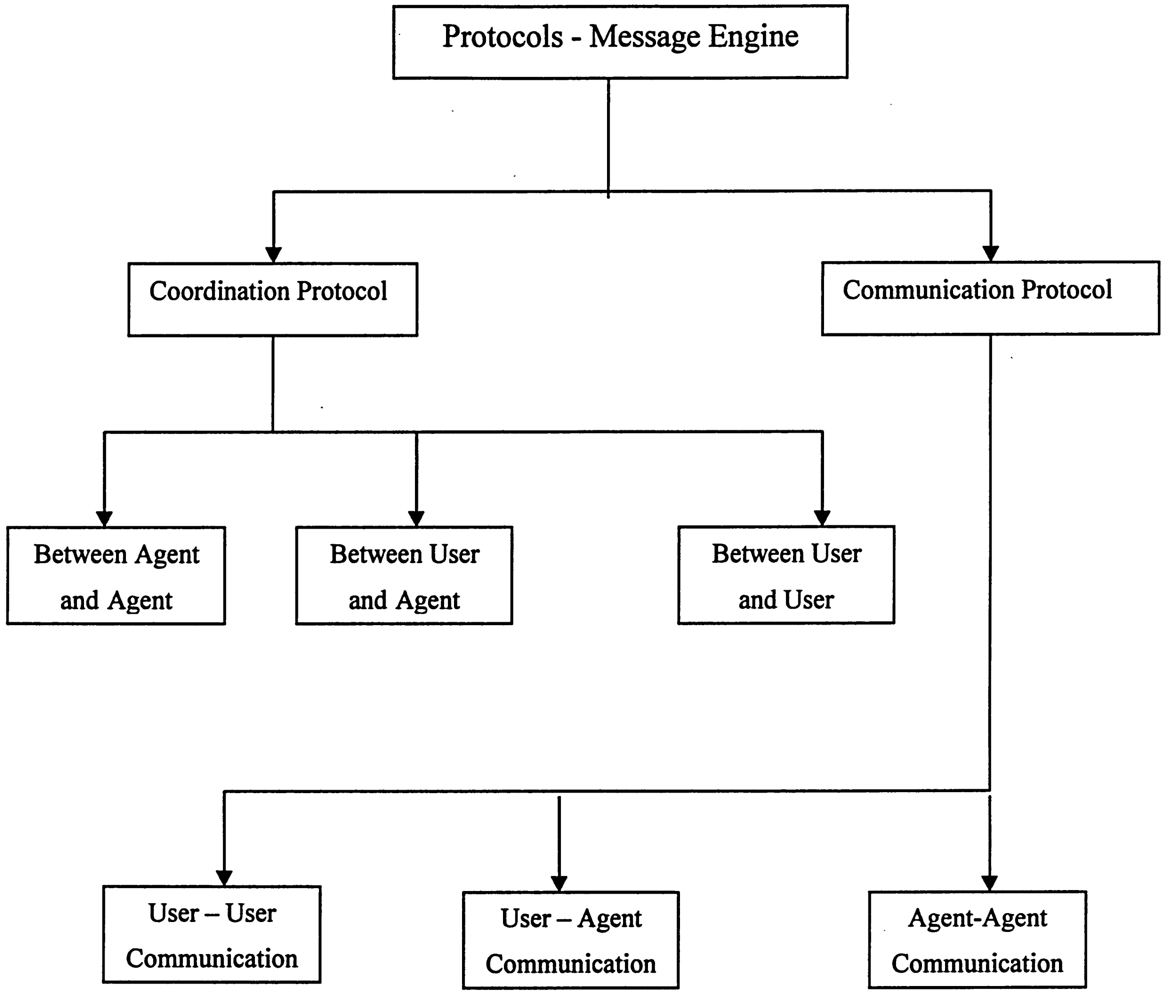


Figure 3.4 Protocols in the Message Engine

Messages between the users and their agent

This form of messages initiates the procurement transaction. The architecture of the specification message resembles the one described in Table 3.2. This form of messages is sub-divided into the following forms of messages.

Buyer_Spec_Msg

This message sends the buyer's specifications to its agent. In this approach, this is the first message that initiates the transaction. It consists of information about the product along with the various requirements and constraints from the buyer.

Message for requests for proposals - Msg_Req_Prop

This message is sent from the buyer agent to the supplier agent. It consists of products or parts, the preferences and the description of their features. The structure of this message is quite similar to the general format of a message.

Supplier_Spec_Msg

This message is from the supplier to its agent. The agent analyses the RFPs and waits for specification messages from its user i.e. the supplier.

Messages for sending responses to proposals- Msg_Response_Prop

These messages are from the supplier agent to the buyer agent. After receiving the RFPs, the supplier agent analyzes the RFPs and creates the responses so as to maximize its gains. The agent interacts with the supplier while making decisions on responses. The message flow is depicted in Figure 3.5.

Buyer_Spec_Upd_Msg

This message is sent from the buyer agent to the buyer. The message consists of updates needed in the request for proposals. The agent communicates about the updates after interaction with the supplier agent.

Buyer_Spec_Upd_Ans_Msg

This message consists of updated information about criteria, features and constraints. It is from the buyer to its agent.

Updated message for requests for proposals – Upd_Msg_Req_Prop

This message is sent from the buyer agent to the supplier agent. It consists of updated information about products or parts, the preferences and the description of their features. The structure of this message is quite similar to the general format of a message. It may be referred to as a counter proposal.

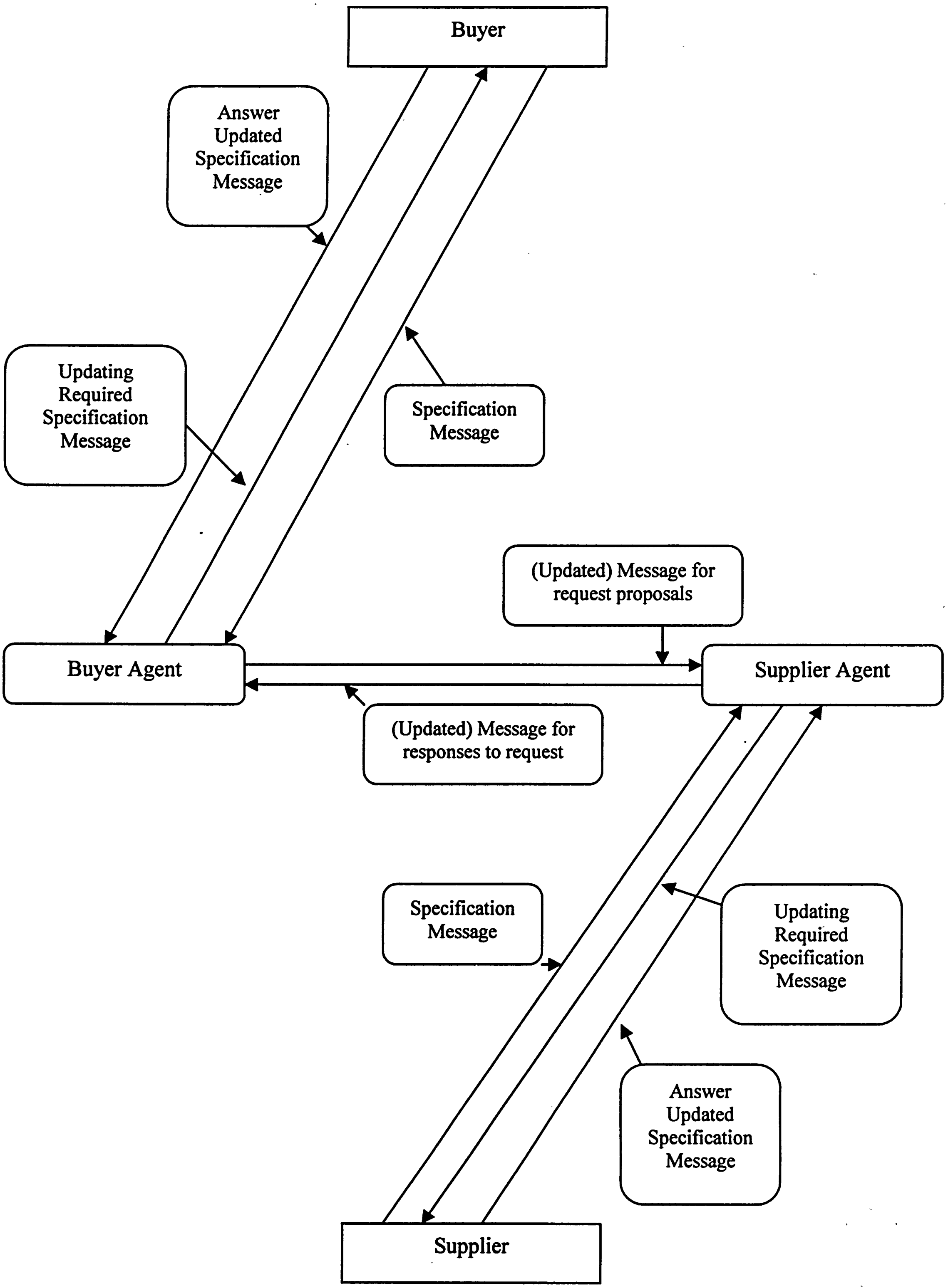


Figure 3.5 Message Flow in the system

Supplier_Spec_Upd_Req_Msg

This message is from the supplier agent to the supplier and consists of updates with respect to responses of suppliers to proposals

Supplier_Spec_Upd_Ans_Msg

This message consists of updated specifications and constraints from suppliers. It is a message from the supplier to its agent and is a response to a counter proposal from the buyer.

3.3.2.3 Coordination Module

The coordination module is responsible for coordinating the message flow between the users and their agents. The coordination module interacts with the communication module and decision engine. The decision engine interacts with the coordination module before assisting the user. The message is sent out to the coordination module that in turn contacts the communication module for further assistance and information. Similarly the coordination module, while sending the messages to the communication module, may ask for information from the decision engine. In short, the coordination module coordinates the activities of all the components. The agent in the coordination module performs all the tasks and works according to the coordination protocol.

Coordination Agent

The coordination agent works for the coordination module. Its main task is to coordinate the flow of messages between various components of the EM and within the coordination module. The task-oriented domain for the coordination agent is denoted as $(TOD)_{cd}$ and is defined as a tuple shown below.

$$(TOD)_{cd} = Tuple\ (T_{cd}, A_{cd}, C_{cd})$$

Where,

a) T_{cd} is the task set for the coordination agent.
b) A_{cd} is the identification of the coordination agent.

a) C_{cd} is a monotonic cost function. C_{cd}: $[2^{T_{cd}}] \rightarrow R^{+}$. $[2^{T_{cd}}]$ stands for finite sets of T_{cd}. and R^{+} denotes the set of positive real numbers. Here, it is clarified that the cost function does not necessarily mean the cost associated with performance of activities or the tasks rather it may relate to any resource such as time or method of processing etc. The cost function for the coordination agent is the amount of time needed to process and coordinate the flow of messages between the various components of the system.

b) $C_{cd}(\phi) = 0$ where ϕ denotes the empty task set of the coordination agent.

Coordination Protocol

The coordination protocol may be divided into three major categories, the coordination between an agent and another agent, the coordination between an agent and a user, and the coordination between a user and another user. Users and their agents initiate the transactions in the EM. The message sent by a user to its agent will consist of specifications related to the part to be purchased and the associated features. For example, the buyer agent in an automobile market should be generally aware of the kind of car or car technology the buyer is interested in. The general knowledge of an agent is updated and enriched after every transaction. For example, if the buyer specifies the airbag, brake system, color and make of the car, etc, then it is easy for an agent to search into him/her database for the specified features. After the search, the agent may store the associated features related to particular transactions in the "storage" for future reference.

In the example above, it is a buyer who sends a specification message to its agent. However, the buyer's agent may receive some responses from the supplier agent regarding the products to be supplied. In this case, the protocol plays a vital role in the agent-agent transactions. Whenever a match is established between the agents, it is the supplier agent who sends responses to a request for proposals from the buyer. Having received a set of responses, the buyer evaluates all of them according to him/her criteria. The user-user transactions come into existence in face-to-face negotiations.

3.3.2.4 Efficiency Functions of Communication and Coordination Agent

The efficiency functions of the communication and coordination agents are inversely proportional to the absolute value of relative error between the desired output and actual output of the message engine to which the agent is committed in a certain period of time. They are denoted as E_{cm} and E_{cd} respectively, and are defined as below.

$$E_{cm} = \frac{1}{1+\left|\dfrac{O_{dcm}-O_{acm}}{O_{dcm}}\right|} \text{ and } E_{cd} = \frac{1}{1+\left|\dfrac{O_{dcd}-O_{acd}}{O_{dcd}}\right|}$$

Where,

a) O_{dcm} is the desired output of the communication agent.
b) O_{dcd} is the desired output of the coordination agent
c) O_{acm} and O_{acd} is the actual output of the communication and coordination agent

If O_{acm} or $O_{acd} = O_{dcm}$ or O_{dcd} within a certain period of time, then E_{cm} or $E_{cd} = 1$, otherwise efficiency functions take a value of between 0 and 1. There is a time constraint, τ, associated with tasks and an agent should be able to complete the tasks within τ. This is the commitment of the agent. The more the agent fulfills its commitment the more efficient it is. When the communication or coordination agent completes the tasks within τ, it gains the maximum efficiency.

The error (O_{dcm} or $O_{dcd} - O_{acm}$ or O_{acd}) at the end of period τ quantitatively indicates the degree to which the task is completed or equivalently the extent to which the agent fulfills its commitment. If the system is still far away from its desired state at the end of τ, the error is large, which means the commitment of the agent is poor. On the other hand, if the system is very close to its desired state, the error will be very small, indicating that the agent fulfills its commitment very well. For the communication and coordination agents, the desired state is the stable state where there is no inflow or outflow of messages between the components of the EM.

3.3.3 Decision Engine

The decision engine consists of the negotiation support module and the proposal evaluation engine. The negotiation support module describes the negotiation mechanism between the buyer agent and the supplier agent in three stages: namely formulations of encounter functions and deal formulation; negotiation protocol and process; negotiation strategies by the buyer agent and supplier agent. The proposal evaluation engine is based on an amalgamation of the AHP and additive value function approaches. The software agent "SupplySelect" is implemented for supplier evaluation and selection.

3.3.3.1 Negotiation Support Module

The Negotiation Mechanism

The objective of buyer and supplier agents is to come to an agreement that is mutually beneficial. It will be necessary for the agents to go through a negotiation or coordination process that will bring them all to a consensus (Rosenschien and Zlotkin, 1994). The mechanism is divided into three stages explained as follows:

a) Space of possible deals – The agents must specify the set of possible deals. For example, the agents might restrict to only discussing deals that do not involve redundant work. Agents may define the deals on one, two or more attributes.

b) Negotiation process – Given a set of possible deals, the agents must define a process that they may use to converge to an agreement on a single deal. The process consists of rules of negotiation. The rules are often termed as protocols. In addition to the negotiation protocol, communication and coordination protocols are defined in the message engine for negotiation.

c) Negotiation Strategy – Given a set of possible deals and a negotiation set, each agent adopts a strategy while participating. The strategy is important for the success of an agent in reaching its objective.

Encounter Function

An encounter function between a buyer agent and supplier agent within task-oriented domains is denoted as $(EC)_{bs}$ and is defined as an ordered list of tasks (T_{bk}, T_{sk}) for all $k \in \{1,2,...,n\}$, where k is set of natural numbers, and it can be represented as a tuple of parameters shown below.

$$(EC)_{bs} = Tuple\ (T_{bk}, T_{sk}, A_b, A_s, C_b, C_s)$$

Where,

a) T_{bk} is an ordered list of tasks of a buyer agent.
b) T_{sk} is an ordered list of tasks of a supplier agent.
c) A_b is an identification of a buyer agent with an ordered list of tasks.
d) A_s is an identification of a supplier agent with an ordered list of tasks.
e) C_b is a cost function of a buyer agent.
f) C_s is a cost function of a supplier agent

A specific "encounter" within task-oriented domains assigns each agent a finite set of tasks. In the definition above, the cost functions take no parameters other than the task set. In general, cost functions might be defined as having other encounter specific parameters (like the initial state of the system). Any agent in task-oriented domains is certain to be able to achieve its goal at that cost. The definition of the cost function guarantees that there will be no negative interaction among agents' goals: the cost of a set of tasks is independent of others. Similarly, and for the same reason, the definition of the cost function rules out positive interactions, or side effects, between the agents that are executing their own sets of tasks.

Formulation of a Deal

This section specifies deals. The first involves evaluation of a deal from the perspective of each individual agent and second involves evaluation of a deal from a group perspective. The simplest kind of deal is distribution of tasks among agents. It is known as a pure deal.

A pure deal for a buyer agent and a supplier agent in their task-oriented domains for an encounter $(T_{bk,} T_{sk})$ is defined as an ordered list (D_{bk}, D_{sk}) for all $k \in \{1,2,\ldots,n\}$ such that

$$D_{bk} \cup D_{sk} \equiv T_{bk} \cup T_{sk}$$

Where,

a) D_{bk} is a deal for a buyer agent.
b) D_{sk} is a deal for a supplier agent.
c) T_{bk} is an ordered list of tasks of a buyer agent.
d) T_{sk} is an ordered list of tasks of a supplier agent.

The cost of such a deal for a buyer or supplier agent is defined as $C\,(D_{bk}, D_{sk}) = C\,(A_s)$ or $C\,(A_b)$ for all $k \in \{1, 2\ldots,n\}$. For each specific deal, both agents evaluate the utility the deal gives to them. The term utility is different from the one commonly used in game theory and economics. Since in a task-oriented domain an agent can always achieve its goal alone, the cost related to it is called a stand-alone cost. Agents compare stand-alone costs to the cost of its part of the deal. The comparison helps agents evaluate the utility of a deal. The utility of any deal ∂ for a given encounter $(T_{bk,} T_{sk})$ for all $k \in \{1, 2\ldots,n\}$ within task-oriented domains is defined as below.

$$Utility_b(\partial) \equiv C(T_{bk}) - C_k(\partial) \text{ and } Utility_s(\partial) \equiv C(T_{sk}) - C_k(\partial)$$

Where,

a) $Utility_b(\partial)$ and $Utility_s(\partial)$ denotes the deal's utility to the buyer and supplier agents respectively.
b) $C\,(T_{bk})$ and $C\,(T_{sk})$ denote stand-alone cost or cost for the buyer and supplier agents to carry its own tasks, respectively.

a) $C_k(\partial)$ is the cost of performing tasks by an agent under a deal.

The pure deal, θ, which is an ordered list (D_{bk}, D_{sk}) for all $k \in \{1, 2, \ldots n\}$, is called a conflict deal. In other words,

$$Pure\ deal\ \theta = (D_{bk}, D_{sk}) \equiv (T_{bk}, T_{sk})$$

The pure deal, θ, is called a conflict deal because no agent agrees to execute tasks other than him/her own. Note that all agents get zero utility from the conflict deal. The buyer and supplier agents are rational and hence are utility maximizers. Each agent thus prefers deals that give more utility to deals that gives less and is indifferent towards deals that give it the same utility.

Negotiation Set

The negotiation set is the set of all deals that are "individual rational" and "Pareto optimal". The negotiation set and protocol help to decide an agent's negotiation strategy. For any deals ∂ and ∂' (Rosenschien and Zlotkin, 1994):

a) It is said that ∂ dominates ∂', and is expressed as $\partial > \partial'$, if and only if $\{Utility_b(\partial), Utility_s(\partial)\} > \{Utility_b(\partial'), Utility_s(\partial')\}$

In other words, ∂ dominates ∂', if ∂ is better for both the buyer and supplier agents.

b) It is said that ∂ weakly dominates ∂', and is expressed as $\partial \geq \partial'$, if and only if $\{Utility_b(\partial), Utility_s(\partial)\} \geq \{Utility_b(\partial'), Utility_s(\partial')\}$ where > holds for at least one agent, but not for both agents. In other words, ∂ weakly dominates ∂', if ∂ is better for at least one agent and not worse for other.

c) It is said that ∂ is equivalent to ∂', if both agents equally prefer ∂ and ∂', and is expressed as $\partial \equiv \partial'$, if and only if

$\{Utility_b(\partial), Utility_s(\partial)\} = \{Utility_b(\partial'), Utility_s(\partial')\}$

In other words, ∂ is equivalent to ∂', if both agents equally prefer ∂ and ∂'.

A deal is individual rational if it gives both agents a non-negativity utility. In other words, a deal ∂ is called individual rational if $\partial \geq \theta$. A deal is called Pareto optimal if there does not exist another deal ∂' such that $\partial' \geq \partial$. It is necessary to specify the possible deals for the agents. Clearly agents in task-oriented domains will not agree to deals that are not individual rational. They would prefer to run into conflicts rather than do extra tasks and get negative utility. This involves evaluation of potential deals from the perspective of each individual agent. It is a criterion that emerges from each agent's individual interests. From the perspective of global considerations, it will be inefficient if the agents agree on a non-Pareto optimal deal.

Negotiation Protocol

The negotiation protocol specifies the rules of negotiation, the rules by which the agents will come to a consensus to carry out one of the deals in the negotiation set. The buyer and supplier agents will start by sequentially proposing one deal from the space of possible deals. An agreement is reached if one of the agents matches what the other one asked for, or offers more than what the other one asked for. If neither agent matches or exceeds the other's demand, the negotiation continues to another round. An agent is not allowed to offer another agent less (in terms of utility) than it did in the previous round. An agent has two choices: to propose a deal with the same utility to other agent in the market, or to propose another deal that gives the other agent more utility. If neither agent concedes at some step, then the negotiation ends, and the protocol specifies that the agreement reached is the conflict deal. The result of this protocol is that agents cannot backtrack, nor can they simultaneously "stand still" in the negotiation more than once.

Negotiation Strategy

Given a negotiation protocol, a negotiation strategy for an agent is to decide what to do next based on the history of the negotiation that is consistent with the protocol. It specifies precisely how an agent will continue, given a specific protocol, and the negotiation up to this point. The strategy is static as it is chosen ahead of time. For an automated agent, that just means that it has been programmed ahead of time, and the programming is not altered.

Negotiation strategies are evaluated on three criteria namely efficiency, stability and simplicity (Rosenschien and Zlotkin, 1994). Agents need a strategy that is stable and results in efficient solutions. The risk evaluation criteria proposed by Zeuthen is used in the proposed EM. A measure of buyer and supplier agents' willingness to risk conflict is proposed. The measurement could result in a simple, efficient and stable negotiation strategy. It is defined as shown below (Rosenschien and Zlotkin, 1994). The proposed strategy is called as "Zeuthen Strategy."

For each step t, and for each agent (A_s) or (A_b), where A_s = s, and A_b = b, let ∂_s^t is an offer made by supplier agent at step t, the degree of willingness to a risk conflict is defined as:

$$Risk_s^t = \begin{Bmatrix} 1 & ,if\ utility_s(\partial_s^t) = 0 \\ \dfrac{utility_s(\partial_s^t) - utiltiy_s(\partial_b^t)}{utiltiy_s(\partial_s^t)} & ,otherwise \end{Bmatrix}$$

Where,

a) $Risk_s^t$ is the risk of the supplier agent at step t of the negotiation process.
b) $Utility_s\ (\partial_s^t)$ is the utility of a deal for the supplier agent at step t.

Similarly a risk function is defined for a buyer agent. At every subsequent step, risk is calculated for each agent. An agent, depending on if its risk is smaller or equal to that of its opponent, makes a decision. In the proposed approach, the buyer and supplier agents use Zeuthen strategy in task-oriented domains. If both agents are using Zeuthen strategy, they will agree on a deal $\partial^* \in$ NS (Negotiation Set) that maximizes the product of agents' utilities such that,

$$\pi(\partial^*) = \max_{\partial \in NS}\{\pi(\partial)\}$$

Where

a) $\pi = utility_b(\partial) \times utility_s(\partial)$. In other words, π is defined as product of agents' utilities.

Let t be a step in a negotiation where both agents use Zeuthen strategy and t is not the last step. There are two possible cases: the first where only one agent concedes, and the second where both agents concede (Rosenschien and Zlotkin, 1994). Let us consider that agent b will be the only one who will make minimal sufficient concession at step $t+1$ if

$$Risk_b^t < Risk_s^t$$

$$\left\{\frac{utility_b(\partial_b^t) - utility_b(\partial_s^t)}{utiltiy_b(\partial_b^t)}\right\} < \left\{\frac{utility_s(\partial_s^t) - utility_s(\partial_b^t)}{utility_s(\partial_s^t)}\right\}$$

$$utility_b(\partial_s^t) \times utility_s(\partial_s^t) > utility_s(\partial_b^t) \times utility_b(\partial_b^t)$$

$$\pi(\partial_s^t) > \pi(\partial_b^t)$$

If $Risk_b^t = Risk_s^t$ then they both will make minimal sufficient concessions as ∂_b^{t+1} and ∂_s^{t+1}. In this case, $Risk_b^{t+1} \leq Risk_s^{t+1}$, from the calculations (Rosenschien and Zlotkin, 1994), it can be seen that $\pi\ (\partial_s^{t+1}) \geq \pi\ (\partial_b^t)$. Hence, it is concluded that $\{max\ (\pi\ (\partial_s^t),\ \pi\ (\partial_b^t)\}$ is a monotonically increasing series. Assume that they agree on deal $\partial \in NS$. If there exists ∂" $\in$ *NS* such that π *(*∂*")* $>$ π *(*∂*)*, then it is discovered that one of the agents should have used ∂" in a prior step in the negotiation, which is a contradiction to the conclusion. Hence, agents agree on a deal that maximizes the product of their utilities (Rosenschien and Zlotkin, 1994). A negotiation strategy described above is said to be in "Nash Equilibrium" under the assumption that if the buyer agent uses strategy *s*, then the supplier agent cannot do better by using a strategy that is different than *s*. The Zeuthen strategy unfortunately is not in equilibrium (Rosenschien and Zlotkin, 1994). If the next step is going to be the last step of the negotiation, the last step can be viewed step as a game in normal form (Rosenschien and Zlotkin, 1994). Rosenschien and Zlotkin (1984) observed that Zeuthen strategy with "last step equilibrium strategy" is in equilibrium and hence making the negotiation simple, efficient and stable.

The new strategy is called as "Extended Zeuthen Strategy" (Rosenschien and Zlotkin, 1994). To summarize, the negotiation support module helps the buyer and the supplier reach an agreement on a possible set of deals in task-oriented domains.

3.3.3.2 Model for Supplier Selection

The basic principle behind the model for supplier selection is an amalgamation method of the additive value function and AHP approaches (Hobbs and Meier, 2000). In the proposed model, the AHP is used for calculating individual and total scores of each supplier. The supplier with the highest total score is selected for the procurement of parts or products.

The Analytic Hierarchy Process

Saaty (1980) introduced the AHP as a tool for dealing with complex decision-making problems. It has been used in various fields such as energy planning, corporate planning, transportation planning and several others (Kamenetzky, 1982). In terms of the AHP, the multiple-criteria decision problem is formulated as a three level hierarchy (Kamenetzky, 1982). The overall objective occupies the first level of hierarchy, the attributes occupy the second level and available options occupy the third level as shown in Figure 3.6. The solution process consists of three stages:

a) Determination of relative importance of the attributes.
b) Determination of relative standing of each option with respect to each attribute.
c) Determination of the overall score of each option.

Determination of relative importance of the attributes

The AHP assumes that every attribute has an unknown measure of importance denoted by w_k where $k = \{1, 2, \ldots, a\}$ and 'a' denotes the set of attributes (Kamenetzky, 1982). If these weights are known, then matrix M with elements $m_{kj} = \{w_k / w_j\}$ is constructed.

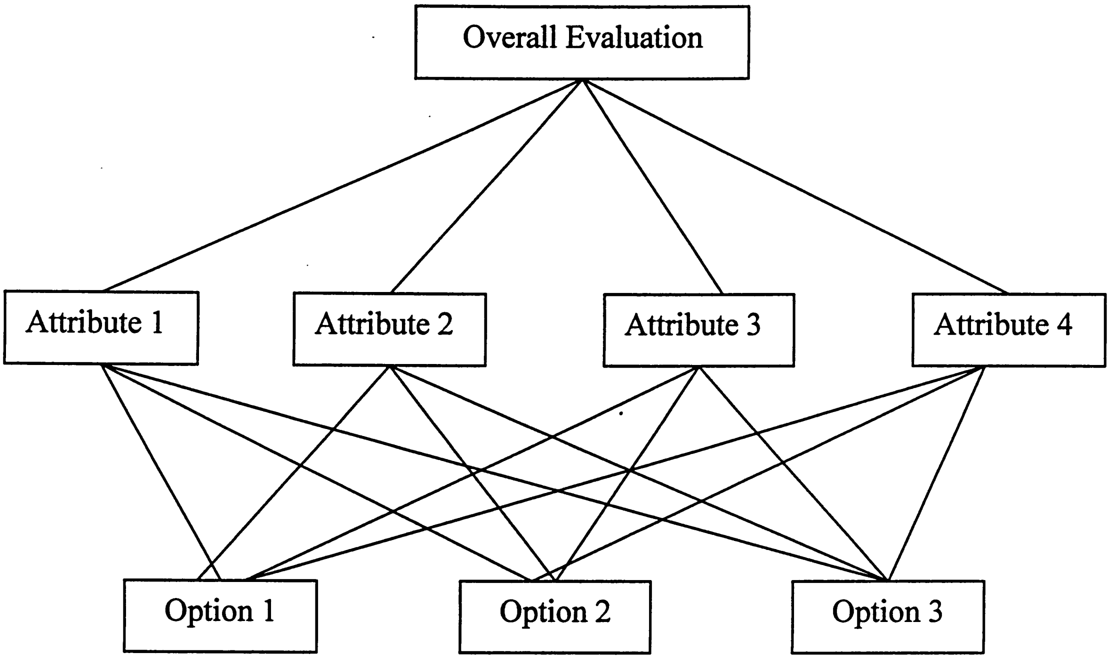


Figure 3.6 Levels of Hierarchy in AHP

The matrix satisfies the equation as shown below.

$$Mw = kw$$

Where,

a) k is the order of matrix.

b) And $w = (w_1, w_2, \ldots, w_a)$

The decision maker is asked to provide an estimate of the matrix M, denoted by M' with elements m'_{kj}. The value of m_{kj} is obtained by asking the decision maker the question: "What is the relative importance of attribute a_k with respect to attribute a_j?" The AHP establishes the following conventions for the construction of matrix M':

a) $m'_{kk} = 1$ *for* $k = \{1, 2, \ldots, a\}$. This follows from the fact that $m_{kk} = \{w_k / w_k\}$.

b) $m'_{kj} = \{1 / m'_{jk}\}$. This ensures symmetry in the judgments of relative importance. The estimate of ratio $\{w_k / w_j\}$ has to be the inverse of the estimate of ratio $\{w_j / w_k\}$.

c) m'_{kj} may only take a value from 1 to 9 or the inverse of these values. This scale is suggested because of the capacity of the human mind to distinguish between several gradations of a characteristic (Saaty, 1980).

Saaty has proven that an estimate w', of true vector weights, w, satisfies the equation:

$$M' w' = e_{max} w'$$

Where,

a) e_{max} is the maximum positive eigen value of M'.

Since there are an infinite number of possible solutions for the above equation, a unique solution is obtained by imposing the scaling constant:

$$\sum_{k=1}^{a} w'_k = 1$$

The measure of importance obtained by this method are ratio scaled.

Determination of relative standing of each option with respect to each attribute

With respect to each given attribute a_k for an option o_m, there is an unknown score attached to it, $w_{m/k}$. These scores can be estimated in a manner analogous to that in which the weights of attributes are estimated by comparing the preference of options with respect to one attribute at a time (Kamenetzky, 1982).

Determination of the overall score of each option

This score is denoted by s_m, and it measures the preference of each option o_m, with respect to all attributes simultaneously. It is given by the equation shown below. The option with the maximum score is selected.

$$s_m = \sum_{k=1}^{a} w'_k \, w'_{m/k}$$

The Analytic Hierarchy Process and Additive Value Function

The valuation of the option o_m on attribute a_k is denoted as $w_{m/k}$. If the preferences of the decision maker are presented by an additive value function V', (Kamenetzky, 1982), then

$$V'(w_{m/1}, w_{m/2} \ldots w_{m/k}) = \sum_{k=1}^{a} V_k'(w_{m/k})$$

Where,

a) V_k' designates a value function over the single attribute k.

Kamenetzky (1982) shown that, if V' is bounded, it can be shown that above equation is equivalent to

$$V'(w_{m/1}, w_{m/2} \ldots w_{m/k}) = \sum_{k=1}^{a} e_k V_k(w_{m/k})$$

Where,

a) V and V_k are scaled from 0 to 1, and $\sum_{k=1}^{a} e_k = 1, \; e_k > 0$

Since $w_{m/k}$ by definition is a measure of preferences with respect to a single attribute, and since the function V_k' is unique up to linear transformation, the total score s_m can be interpreted as the evaluation of the additive value function (Kamenetzky, 1982).

Hence, the AHP is used to construct an additive value function in the decision engine of the proposed EM. Based on the above theory, the methodology of supplier selection is explained below.

3.3.3.3 Proposal Evaluation Engine

The proposal evaluation engine is an important part of the decision engine. This module serves as a base for supplier selection and evaluation. The module utilizes the AHP for supplier selection and evaluation. Figure 3.7 shows the hierarchy of levels for supplier selection. It can be observed that each level has its own significance.

Level 1: The aim is the selection of the best supplier amongst the number of suppliers available. Level 1 indicates the objective of the decision process.

Level 2: This level of hierarchy consists of the attributes of the selection process. Suppliers are evaluated on these attributes. The user decides the number of attributes in the selection process during proposal formulation. In the proposed approach, the following five attributes are considered, which play a vital role in the supplier selection process.

Price-performance: Every user wants profit maximization. Profit maximization for a buyer cannot be achieved without price minimization. Price includes sub-attributes such as purchase price etc.

Quality-performance: Quality of products to be purchased is an important factor for supplier evaluation and selection, as the total cost of the finished product depends on the quality of raw material or parts procured from suppliers. Practically speaking, buyers deal with quality-certified suppliers.

Service-performance: Service includes on-time delivery, technical assistance provided by the supplier, time required for communication and the mode of payment. Delay in delivering products by the supplier may disrupt the process of production. So, on-time delivery of purchased products is very essential.

Technology-performance: Each buyer or supplier needs to know the technology of the other. The technologies should be compatible with each other. The prototype design, the material used and the technology in existence help determine the process of production.

Supplier Past-performance: This attribute combines all the factors mentioned above. A buyer rates the suppliers who have participated in the selection process on the basis of subjective assessment. The supplier with high overall ranking is preferred. Buyers keep a record of a supplier's performance in the storage of transactions.

Level 3: This level indicates the sub-attributes. The sub-attributes related to the above attributes are discussed in detail below.

Price-performance related sub-attributes: In addition to purchase price, price may include transportation cost, manufacturing cost etc.

Quality-performance related sub-attributes: It includes quality control procedures, product specifications and preference of the approved or certified suppliers

Service-performance related sub-attributes: It includes on-time delivery, communication time, and technical assistance provided to the user.

Technology-performance related sub-attributes: It includes assessment of technology-in-use, supplier design capabilities and supplier speed in development

Supplier-performance related sub-attribute: It includes the performance of supplier on each of the above-mentioned attributes

Level 4: This level indicates various options or alternatives. In the proposed approach, the buyer may consider alternative suppliers.

In the proposed approach, the basic principle underlying supplier selection is an amalgamation of additive value function and AHP. The additive value function uses the total score to evaluate and rank the alternatives. The four steps in supplier selection process are explained as follows:

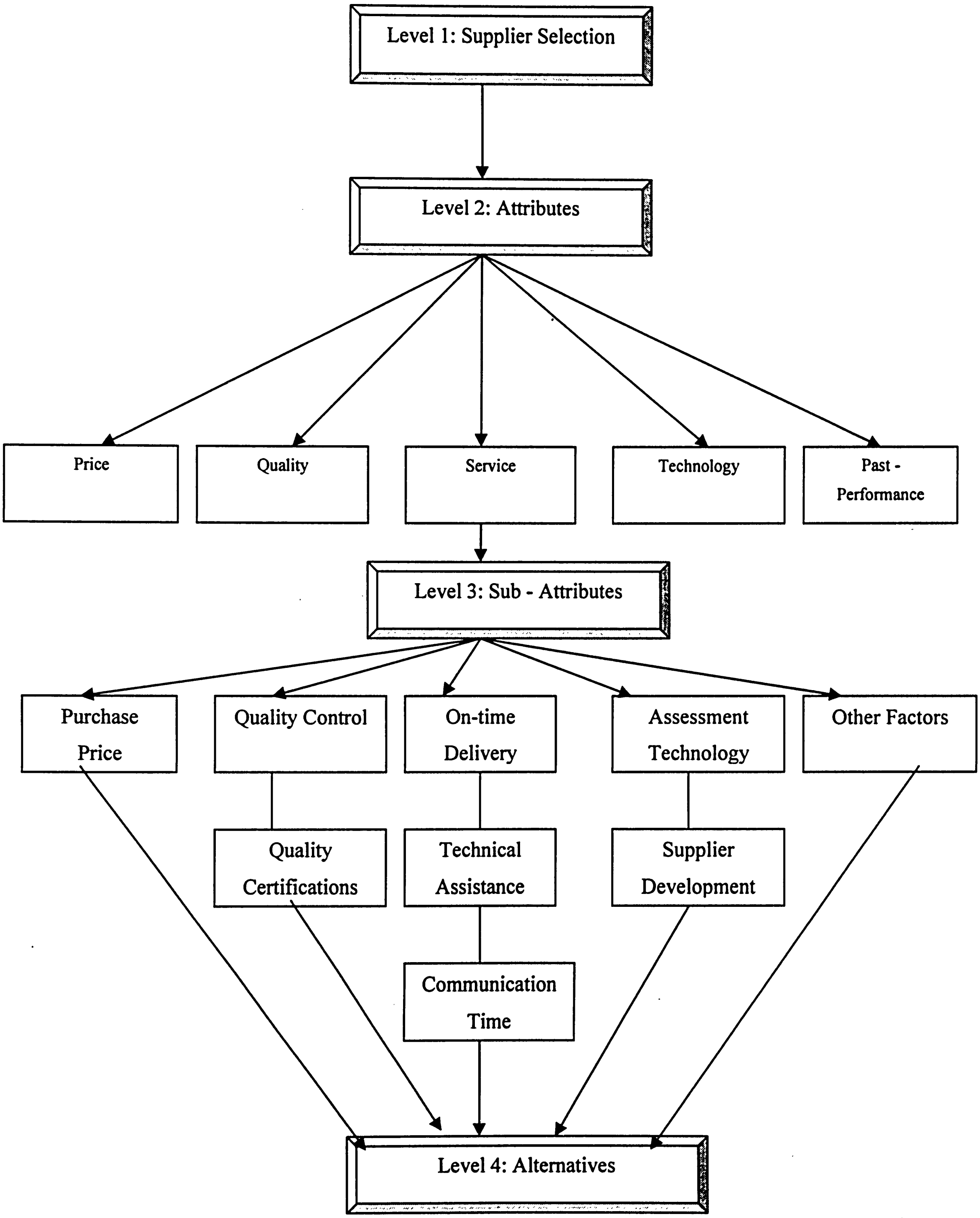


Figure 3.7: Hierarchy of Supplier Selection

Step 1: Calculation of Overall Weight, OW_i, of each Attribute

After selection of attributes, AHP is used to calculate the overall weight of each attribute. The measurement scale, shown in Table 3.1 is used for pairwise comparison of attributes. If sub-attributes are considered, the weight of each sub-attribute for a given attribute is calculated. For example, if service-performance is the attribute, and on-time delivery, technical assistance and communication time are sub-attributes, then calculation of the weight for each sub-attribute is done using pairwise comparison and the weights are added to obtain the overall weight of service-performance. Mathematically, the overall weight is calculated by the equation below.

$$OW_i = \sum_{k=1}^{l} W_{ik}$$

$$i = 1,2,\ldots n$$

Where,

a) W_{ik} = Weight of sub-attribute k, for attribute i.
b) OW_i = Overall weight of attribute i.

Step 2: Calculation of Individual Score of Supplier for each attribute, IS_{jik}

Individual score of supplier for each attribute is calculated using AHP. In AHP, the lowest level of hierarchy with respect to the level of criteria immediately above is assessed. In this model, the lowest level of hierarchy, which includes suppliers, is compared with the level immediately above it. This comparison provides the individual score of supplier with respect to each attribute. The overall weight is obtained in the first step. The greatest strength of AHP is to encourage decision makers to be more careful as to what is important in a particular decision and to how the available alternatives perform with respect to objectives. If more than one decision-maker is involved such an analysis can be a means of facilitating, communication and understanding. The AHP is used in both, criteria comparisons and individual aspects within each criterion.

Table 3.1 Measurement Scale (Saaty, 1980)

Verbal Judgment or preference	Numerical Rating
Extremely preferred	9
Very strongly to extremely preferred	8
Very strongly preferred	7
Strongly to very strongly preferred	6
Strongly preferred	5
Moderately to strongly preferred	4
Moderately preferred	3
Equally to Moderately preferred	2
Equally preferred	1

Step 3: Calculation of Total Score, TS_j

Total Score is calculated using the following equation:

$$TS_j = \sum_{i=1}^{n} IS_{ji} OW_i$$

Where,

a) IS_{ji} denotes individual score of each supplier j for attribute *i*.

b) TS_j denotes the total score of supplier *j*.

c) OW_i denotes overall weight of each attribute *i*.

If we consider sub-attributes in the selection process, then equation for calculation of the total score is shown below:

$$TS_j = \sum_{i=1}^{n} \sum_{k=1}^{l} IS_{jik} W_{ik}$$

Where,

a) TS_j is the total score of supplier *j*.

b) W_{ik} is weight of sub attribute k for attribute *i*.

c) IS_{jik} is individual score of supplier j for sub attribute k and attribute *i*

Step 4: Selection of Supplier

The supplier with the highest total score is selected. Buyers may choose different suppliers for different attributes by analyzing the individual scores of suppliers. The approach for supplier selection is illustrated using three suppliers and four attributes as shown below.

3.3.3.4 A Numerical Illustration

To illustrate the approach of supplier selection, an example is presented. It is assumed that four criteria are used to evaluate suppliers:

a) Price of the part,

b) Quality,

c) Service, and

d) Technology in use.

It is assumed that three suppliers participate in the procurement process. The next step is to develop a pair-wise comparison matrix to give a numerical weighting to each criterion based on the measurement scale shown in Table 3.1. The process begins with the development of a matrix that compares each criterion with others under consideration. The matrix for the four criteria in this illustration is given in Table 3.2. In general, for any pairwise comparison matrix, 1s are placed down the diagonal from the upper left-hand corner to the lower right-hand corner. Then comparing the respective criteria, the rest of cells are populated.

In this example, it is assumed that price is moderately preferred to quality; hence, starting at the upper left hand corner of the original matrix, four is placed. Using the same scale, price is extremely preferred to service; hence, nine is at the intersection of price and service in row one. And, as price is very strongly-to-extremely preferred to technology, eight is placed in the top right-most cell, hence completing row one.

Similarly, the other cells are populated. On the flip side of the diagonal 1/4, 1/8 and 1/9 are placed in column 1, for the comparison of quality with price, technology with price and service with price respectively. Other cells are filled in an identical manner. Table 3.2 indicates the criteria matrix or original matrix showing pair wise comparisons. The buyer provides pairwise comparisons.

Table 3.2 Attribute Weighting Matrix

Original Matrix

Criteria/ Criteria	Price	Quality	Service	Technology-in-use
Price	1	4	9	8
Quality	0.250	1	3	7
Service	0.111	0.333	1	5
Technology-in-use	0.125	0.143	0.200	1
Column Totals	1.486	5.476	13.2	21

Once these comparisons are made, the data are used for determining weights. The process is carried out in three steps:

1) Sum the elements of each column
2) Divide each element by its column total
3) Compute row averages

Table 3.3 Attribute Weighting Matrix

Adjusted Matrix

Criteria	Price	Quality	Service	Technology	Weights
Price	0.672	0.730	0.681	0.380	0.616
Quality	0.168	0.183	0.227	0.333	0.228
Service	0.075	0.061	0.077	0.238	0.113
Technology	0.084	0.026	0.015	0.048	0.043

Hence, the weights are 0.616, 0.228, 0.113 and 0.043 for price, quality, service and technology, respectively. In this methodology, the next step is to compare the three suppliers on how they perform on these criteria. The original matrices are shown below for the three suppliers and four evaluation criteria. The adjusted matrices are shown along with the original matrix. The process followed for determining the scores of each supplier with respect to the criterion under consideration is identical to that described above. Tables 3.4 and 3.5 indicate the comparisons with respect to price.

Table 3.4 Pair wise comparisons of suppliers with respect to "Price" evaluation criterion

Original Matrix

No. of Suppliers	Supplier 1	Supplier 2	Supplier 3
Supplier 1	1	5	7
Supplier 2	0.200	1	5
Supplier 3	0.143	0.200	1
Column Totals	1.343	5.200	13

Table 3.5 Pair wise comparison of suppliers to "Price" evaluation criteria

Adjusted Matrix

No. Of Suppliers	Supplier 1	Supplier 2	Supplier 3	Weights
Supplier 1	0.745	0.961	0.538	0.748
Supplier 2	0.149	0.192	0.385	0.242
Supplier 3	0.106	0.038	0.077	0.073

Hence, from the calculations in Table 3.5, it is clear that for the price evaluation criterion, supplier 1 has a score of 0.748; supplier 2 has a score of 0.242, and supplier 3, 0.073. Tables 3.6 and 3.7 show calculations for the quality evaluation criterion.

Table 3.6: Pair wise comparisons of suppliers with respect to the "Quality" evaluation criterion

Original Matrix

No. Of Suppliers	Supplier 1	Supplier 2	Supplier 3
Supplier 1	1	7	0.166
Supplier 2	0.143	1	4
Supplier 3	6	0.250	1
Column Totals	7.143	8.250	5.166

Table 3.7: Pair wise comparisons of suppliers with respect to "Quality" evaluation criterion

Adjusted Matrix

No of Suppliers	Supplier 1	Supplier 2	Supplier 3	Scores
Supplier 1	0.140	0.848	0.032	0.340
Supplier 2	0.020	0.121	0.774	0.305
Supplier 3	0.840	0.030	0.193	0.354

Calculations indicate that supplier 1, supplier 2, and supplier 3 have scores 0.340, 0.305 and 0.354, respectively, for the quality evaluation criterion. Similarly, the individual scores of each supplier for service and technology are carried out as shown in the Tables 3.8, 3.9, 3.10 and 3.11.

Table 3.8 Pairwise comparisons of suppliers with respect to "Service" evaluation criterion

Original Matrix

No of Suppliers	Supplier 1	Supplier 2	Supplier 3
Supplier 1	1	4	6
Supplier 2	0.250	1	5
Supplier 3	0.166	0.200	1
Column Total	1.416	5.200	12

Table 3.9 Pairwise comparisons of suppliers with respect to "Service" evaluation criterion

Adjusted Matrix

No of Suppliers	Supplier1	Supplier 2	Supplier 3	Scores
Supplier 1	0.706	0.770	0.500	0.658
Supplier 2	0.176	0.192	0.416	0.261
Supplier 3	0.117	0.038	0.083	0.079

Table 3.10 Pairwise comparisons of suppliers with respect to "Technology" evaluation criterion

Original Matrix

No of Suppliers	Supplier 1	Supplier 2	Supplier 3
Supplier 1	1	0.166	4
Supplier 2	6	1	3
Supplier 3	0.250	0.333	1
Column Totals	7.250	1.499	8

Table 3.11 Pairwise comparisons of Suppliers with respect to "Technology" evaluation criterion

Adjusted Matrix

No of Suppliers	Supplier 1	Supplier 2	Supplier 3	Scores
Supplier 1	0.138	0.111	0.500	0.249
Supplier 2	0.827	0.667	0.375	0.623
Supplier 3	0.034	0.222	0.125	0.127

The final table of calculations is constructed which indicates the overall score of each supplier for different evaluation criteria. For example, to calculate the final score of supplier 1, first calculate supplier score (or weight) for the price, quality, service and technology criteria. To calculate the score for the price factor, multiply the score of supplier 1 for the price factor with price factor weight from the attribute-weighting matrix. The results are shown in Table 3.12.

Table 3.12 Total Score

Criteria/Suppliers	Price	Quality	Service	Technology	Total Score
Supplier 1	0.461	0.078	0.074	0.011	0.624
Supplier 2	0.149	0.070	0.029	0.027	0.275
Supplier 3	0.045	0.081	0.009	0.005	0.140

From the calculations, supplier 1, supplier 2, supplier 3 have total scores of 0.624, 0.275 and 0.140 respectively. Therefore, supplier 1 is selected. The total score of each supplier depends entirely on judgments given by the buyer to suppliers during the calculations of the individual scores of each supplier and of the weights of the attributes.

3.3.3.4 Supplier Selection System – SupplySelect

SupplySelect is a software agent developed for the proposed marketplace for supplier selection. The agent is a part of the decision engine. The method for supplier selection is discussed in detail in Section 3.3.3.4. SupplySelect is a graphical user interface, which helps in visualizing the process of supplier selection. It can be called as a prototype supplier selection system, which is constructed on MS-Access. MS-Access acts both, as back-end and front-end. The back-end stores the databases or tables and the user operates the front-end and retrieves data from the back-end.

Advantages of Using MS-Access

Advantages of using MS-Access as a platform are as follows:

a) The tools provided by MS-Access are user friendly so that a user with minimum skills can access them with ease. The main tools are forms, reports, tables and queries. Tables store data related to different fields in the software. Forms are basically comprised of blocks and fields. Multiple tables can be accessed over a single form, based on the application with the help of the transaction command.

a) Reports are used for developing, executing, displaying and printing reports. Queries are the statements used for retrieving information from the tables.

b) The programming environment displays a list of available components. The user picks up the required component from this list for display. The components can be moved, resized, and even deleted, if required.

c) MS-Access reduces the time taken to communicate between the application and the server, thus enhancing efficiency.

d) MS-Access allows us to manipulate data values in the table more flexibly and effectively. Above all, it is easy to use, learn and an attractive tool to demonstrate an application like SupplySelect.

Architecture of the SupplySelect

The flowchart depicting the function of the system is illustrated in Figure 3.8. The users of the system are provided a login-id and password. The buyer starts the procurement process by putting forward the RFPs. He selects the parts to be purchased. After the parts selection, the buyer selects attributes. The supplier with the highest total score is selected. The suppliers are also ranked for each attribute. SupplySelect is constructed using forms and tables in MS-Access. The various forms and tables are discussed in detail in Chapter 4.

Forms are used for the construction of various windows implemented in the system. It includes login-form, parts-form, attributes-form, and scores-form. The login-id form helps the user to enter into the system by entering his or her login-id and password. The parts-form shows various parts on the screen. The attributes-form shows the various attributes that include price, quality, service and technology-in-use.

The scores-form indicates the scores obtained by each supplier and weights of each attribute. The various forms serve as the front-end of the software agent. The tables are used to store data values for each field. Five major tables are created for software implementation. The tables serve as a back-end for the software. The tables include a login-table, which stores the login-id and password of the users. The supplier-table stores suppliers and their identification codes. The parts-table consists of parts and their identification codes.

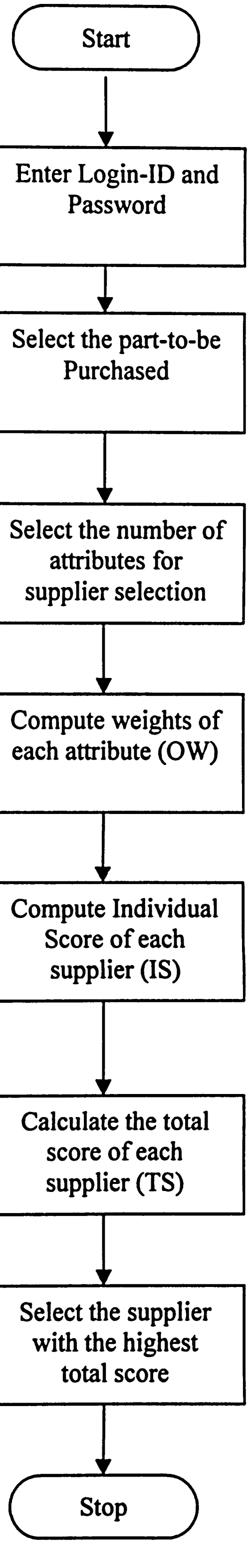


Figure 3.8 Flowchart for Supplier Selection

The attribute-table consists of data-values of all the attributes for each supplier and part. The measurement-scale table stores values, 0 to 9, which indicates verbal judgments for ranking suppliers. The implementation of the software and a real-world application are discussed in Chapter 4. As "SupplySelect" is based on the AHP, it evaluates and selects supplier systematically and produces accurate results.

3.3.4 Knowledge Base

The knowledge base acts as a database for the proposed EM. The knowledge base is divided into three sub databases; the buyer and buyer agent's database, the supplier and supplier agent's database, and the shared databases. The buyer and its agent's database consists of information about the suppliers, data about the products to be purchased, information about products features, and data for proposal and counter proposal formulations. The architecture of the supplier's database is similar to that of the buyer's. It consists of data about products to be sold, information about new products and information about how to respond to the buyer's requests. The buyer's database is accessible to buyer and its agents only. Similarly, the supplier's database is accessible to supplier and its agents only.

The shared database contains information relevant to the buyer, supplier and their agents. It provides real-time information about business markets and hence helps the users and their agents to make decisions to maximize their profits. The shared database is important as it helps both, the supplier and the buyer to improve their functions. This database "lives on" the Internet and hence provides real-time information, which is more relevant and important to the buyer, supplier and their agents.

The database of the software agent, SupplySelect, is connected to the knowledge base and the agent accesses data in real-time, during supplier evaluation and selection. The knowledge base derives a user's profile and gains new insight and a better understanding of the user's needs that can be used further to improve services offered by the proposed EM. The diagrammatic representation is shown in Figure 3.9. The agent in the knowledge base is defined in a task-oriented domain. The task of the knowledge agent is data retrieval for the buyer agent, supplier agent, agents in a message engine and the software agent, SupplySelect.

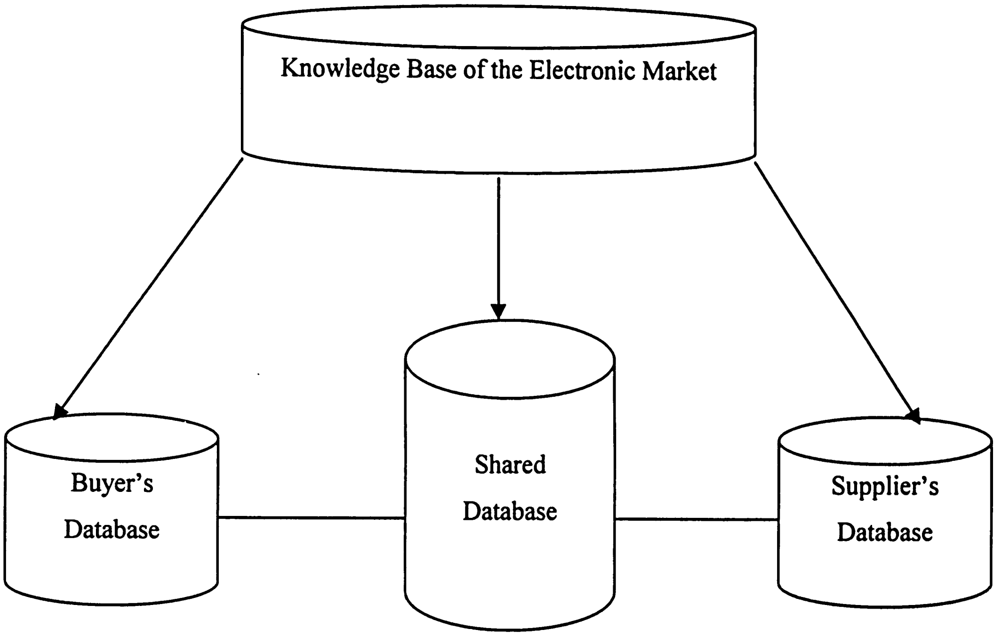


Figure 3.9 Structure of the Knowledge Base

Agent for the Knowledge Base

The main task of the agent in the knowledge base is to carry out database queries. An agent has access to the database and it responds to queries of other agents in the system. The task oriented domain for an agent in the knowledge base is also called as "Postmen and Delivery" domain. It is denoted as $(PD)_{kb}$ and defined as below.

$$(PD)_{kb} = Tuple\ (T_{kb}, A_{kb}, C_{kb})$$

Where,

a) T_{kb} is the task set for the agent. It includes all possible queries, expressed in the primitives of relational database theory. For example, buyer and supplier agents may want to access information for updates on a deal.
b) A_{kb} is the identification of the agent.

c) C_{kb} is the monotonic cost function. $C_{kb} :[2^{T_{kb}}] \rightarrow R^+$, where $[2^{T_{kb}}]$ stands for finite subsets of T_{kb} and R^+ denotes the set of positive real numbers. The cost function is the cost of set of queries that are needed to generate one record.

d) $C_{kb}(\phi) = 0$ where ϕ is the null set of task.

3.3.5 Storage of Transactions

The history of transactions that a user and its agent participated is stored in storage of transactions. In this way the importance is given to the storage of transactions as it helps the decision makers to refer to the history for decision-making. It stores information related to various transactions. For example, suppose a buyer, say, Ford Motor, puts forward its RFP to Chalmers Suspension International Inc. for the procurement of a gear. The system will record the type of messages and message flows between Ford Motor and Chalmers Suspension International Inc. Such storage may be utilized for future transactions. This component of the system consists of information stored in sequence. The agent in storage works with the knowledge agent for database queries. The agent is task oriented and hence defined in the "Postmen and Delivery" task domain. The agent reduces the transaction time and cost in data retrieval, hence increasing the efficiency of the proposed EM. The efficiency functions for knowledge and storage agents are defined in the next section.

Agent for the "Storage of Transactions"

The functioning of the agent is similar to the agent in the knowledge base. The transactions are stored for future reference. The main purpose of the agent in the storage is retrieval of data.

The task domain is classified as "Postmen and Delivery " domain. It is denoted as $(PD)_{st}$ and defines as below.

$$(PD)_{st} = Tuple\ (T_{st}, A_{st}, C_{st})$$

Where,

a) T_{st} is the set of tasks. For example, a buyer agent may want information about its previous formats of RFPs for gear.
b) A_{st} is the identification for agent.
c) C_{st} is monotonic cost function. Cost function in this case is the minimum length of time taken to create one record. $C_{st} : [2^{T_{st}}] \rightarrow R^{+}$, where $[2^{T_{st}}]$ stands for finite subsets of T_{st} and R^{+} denotes the set of positive real numbers.
d) $C_{st}(\phi) = 0$ where ϕ is the null task set.

Efficiency Functions of Knowledge and Storage Agent

The efficiency functions of knowledge and storage agents are inversely proportional to the absolute value of relative error between the desired output and actual output of the message engine to which the agent is committed in a certain period of time. They are denoted as E_{kb} or E_{st}, and are defined respectively as below.

$$E_{kb} = \frac{1}{1+\left|\frac{O_{dkb} - O_{akb}}{O_{dkb}}\right|} \text{ and } E_{st} = \frac{1}{1+\left|\frac{O_{dst} - O_{ast}}{O_{dst}}\right|}$$

Where,

a) O_{dkb} is the desired output of the knowledge agent.
b) O_{dst} is the desired output of the storage agent.
c) O_{akb} and O_{ast} is the actual output of the knowledge and storage agent.

If O_{akb} or $O_{ast} = O_{dkb}$ or O_{dst} within a certain period of time, then E_{kb} or $E_{st} = 1$, otherwise the efficiency functions take a value of between 0 and 1. There is a time constraint τ associated to the tasks and an agent should be able to complete tasks within τ time. This is the commitment of the agent. More often the agent fulfills its commitment; higher will be its efficiency increase. When the knowledge or the storage agent completes the task within τ, it gains maximum efficiency.

The error (O_{dk} or $O_{dst} - O_{ak}$ or O_{ast}) at the end of period τ quantitatively indicates the degree to which the task is completed, or equivalently the extent to which the agent fulfills its commitment. If the system is still far away from its desired state at the end of τ, the error is large, which means the commitment of the agent is poor. On the other hand, if the system is very close to its desired state, the error will be very small, which shows that the agent fulfills its commitment very well. For knowledge and storage agents, the desired output is the stable state where there is no set of database queries waiting to be executed. The efficiency functions keep check on the functionality of agents.

3.4 User Interface of the Proposed Electronic Marketplace

The user interface of the proposed EM consists of components that can be accessed by potential users either buyers or suppliers through an interface implemented as a website, providing all services at one place. The conceptual model of the interface consists of the following components as depicted in Figure 3.10.

a) Catalogues – Catalogues display the list of products, especially more sophisticated or customized products. The customized products are made available on special request.
b) Resource Center – This center provides information with related links. For example, in the proposed approach, the resource center provides information about the other EMs that offer similar kinds of products and services. The resource center also includes pressroom, executive biographies, membership and history of users. It may link users to external service providers such as stock exchanges, and other relevant financial and business data.
c) Help Center – This center helps users communicate via ordinary telephone calls, electronic mail, traditional mail and other forms of communication. Software agents could handle some common questions and requests. Workflow management technology could be employed to automate and coordinate the tasks necessary to respond to users requests. Human experts would analyze user requirements at different levels and suggest possible solutions through the electronic marketplace. Special consultants or representatives may be appointed for special problems.

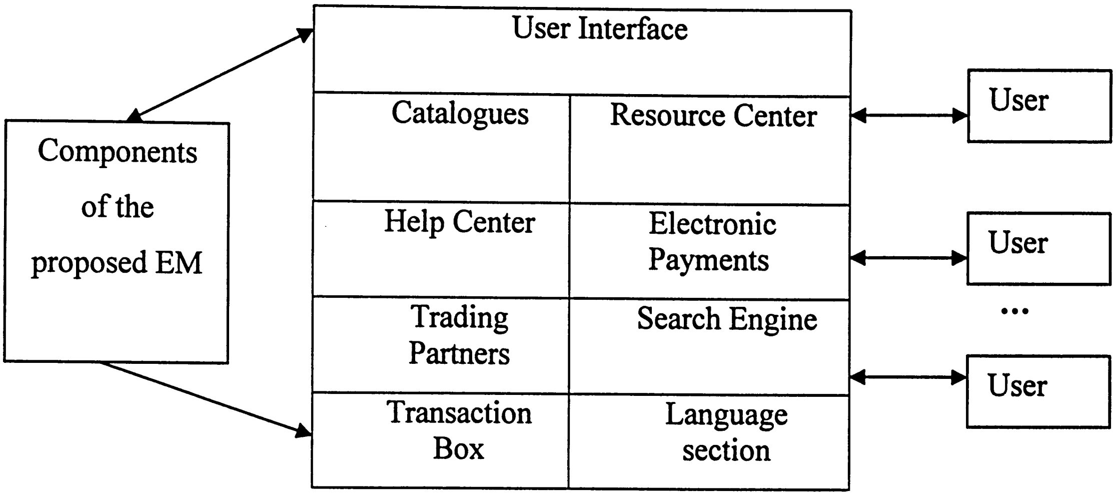


Figure 3.10 Components of the User Interface

d) Electronic Payment – The payments are settled electronically through digital contracts and digital signatures. Electronic payments have now matured remarkably as far as securities of electronic monetary transactions are concerned. Accounts are created for each user that maintains the details of various transactions including micro payments, lump-sum payments, installment plans and possibly the creation of a new form of digital cash. The security and confidentiality must be absolutely guaranteed.
e) Trading Partners – In the proposed approach, the database of trading partners is suggested, which consists of links to each partner and their evaluation systems. For example, all automobile manufactures such as Ford, GM, and Lear may register themselves as trading partners with links to their electronic evaluation engines.
f) Search Engine –The search engine is included as a component of an external framework. The users may want to search other options on the web through this search engine.
g) Transaction Box – This box is similar to a shopping cart in a shopping mall where users store the information about products or parts of interest and digital contract etc for a particular transaction. The transaction box is created each time users utilizes the proposed EM.

a) Language Section – This section helps users from different part of the globe to register in the marketplace and use the facilities available on it.

To summarize, a user interface through a web popularizes the proposed design of EM. Continuous improvement is carried out depending on user's feedbacks.

3.5 Proposed Approach and Existing Designs

This section compares the proposed approach with the existing designs of EMs. Kia et al, (2002) have designed a three-layer agent architecture for product search and retrieval. In the proposed approach, a multi-agent system for procurement is designed, which not only deals with product search and retrieval but also with the information related to users and their transactions. It is noticeable that an agent is not linked with any specific EM. Ben-Ameur et al. (2002b) suggest the shared information space for negotiation exchanges and states and described the coordinator and service agents for e-procurement that are comparable with the coordination and communication agents in the proposed approach. Davidrajuh (2003) suggested a multiagent model of partner selection with three stages -- bidder selection, partner selection, and performance evaluation. Faratin et al., (1998) have used autonomous agents for negotiations. The agents are concerned with various departments. There exist various kinds of agents such as mobile agents, goal oriented agents and communicative agents (Clements et al., 1997). In this thesis, task-oriented agents are proposed for the EM. Lang and Whinston (1999) examined the design of decision support systems for EMs. Lang and Whinston (1999) concentrate on the decision support systems rather than the actual design of EMs. The electronic storefront is comparable with user interface in the proposed approach. To summarize, existing electronic marketplaces either lack a systematic decision support system or are inordinately biased towards the use of agents. Hence, the proposed approach is efficient, simple and stable.

Chapter 4 Implementation of the Supplier Selection System – "SupplySelect" and a Case Study

4.1 Introduction

As described in Section 3.3.3.5, SupplySelect is a software agent of the decision engine of the proposed EM and is based on Microsoft Access. As the selection system is part of the proposed EM, so users must register in the proposed EM to access the system. This chapter explains the implementation in detail. Section 4.2 gives an overview of the implementation process. Section 4.3 describes the various forms and tables in detail. Section 4.4 compares the proposed system with some of existing approaches. In Section 4.5, a case study conducted at Chalmers Suspensions International Inc. is presented that demonstrates the practical implications of the system.

4.2 Overview of the Implementation Process

SupplySelect, a supplier selection system, is installed on the computer system through step-by-step implementation of various forms and tables. The forms serve as the front-end and tables as the back-end of the supplier selection system. The system consists of login-form, parts-form, attribute- form, and original and adjusted matrix forms for price, service, quality and technology-in-use. It also consists of original and adjusted matrix forms for scoring for each attribute and forms for the total score. Each form has its corresponding table such as login-table, parts-table etc. The detail description and the implementation of the forms and tables are discussed in the next section. The system is completely implemented and ready to use after installation of all the forms and tables.

4.3 Implementation of the System

SupplySelect is compatible with operating systems such as MS Windows 95, MS Windows 98, MS Windows 2000 and MS Millennium The implementation is based on following considerations:

a) The implementation is illustrated by using three suppliers who participate in the procurement process. However, the system is flexible to the number of suppliers.
b) Four attributes are considered; price, quality of the part or product, service performance and technology of the supplier.
c) It is assumed that a buyer initiates the transaction by putting forward a RFP. Hence a buyer logs into the system through the proposed EM and utilizes the system to arrive at a decision.
d) A buyer selects only one part from the list of the parts provided on parts-to-be purchased form.
e) The system is considered equally suitable for the existing suppliers as well as new suppliers of the firm.

4.3.1 Login Form

Users (buyers or suppliers) register in the proposed EM by filling-up the registration forms. Registration forms ask for primary information of the user such as user's first and last name, the organization of the user, its address, telephone or email etc. Users have to abide by the policies and regulations of the EM. They are assigned login identification codes and a secret password. They are recognized by identification codes for every transaction.

Figure 4.1 shows the "Login Form" for SupplySelect. Users are advised to utilize registered login identification codes and passwords. SupplySelect identifies a user by its login identification code and password. However, a user may enter the supplier selection system by creating a new identification code and password specific to the SupplySelect. The login identification codes and passwords are stored in the "Login-Table".

The structure of the login table is depicted in Table 4.1. It consists of two fields: Login-ID and Password. The table illustrates five users and their respective passwords in the login table. The user's code and password are automatically stored in the login-table. The table is updated for every new registration.

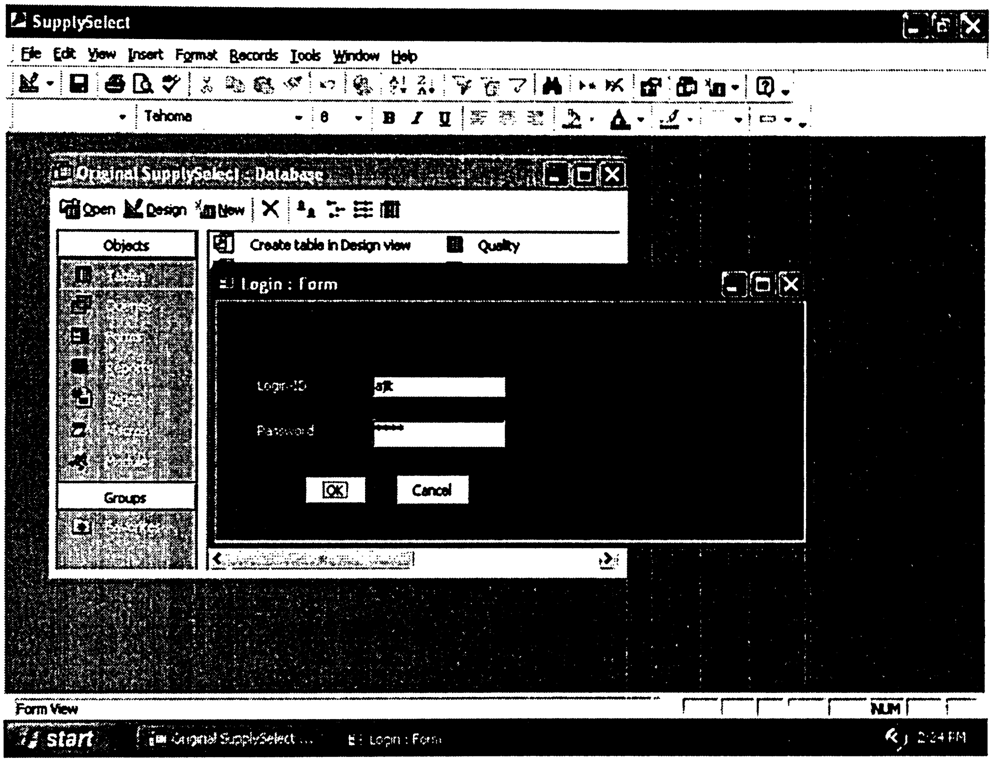


Figure 4.1 Login Form

Table 4.1 Login – Table

Login-ID	Password
User 1	******
User 2	****
User 3	*******
User 4	*****
User 5	*******

4.3.2 Parts Form

A buyer identifies the purchasing needs of the firm at the initial stage of procurement. This step may be accomplished by production analysts or decision makers or may be automatically generated by enterprise resource planning packages. The needs of the buyer's company may vary from a long-term strategic supply of raw materials to spot purchasing of indirect goods like new computers for the purchasing department.

The parts manager maintains the list of parts or products in the knowledge base of the marketplace. Parts manager transfers the data from the knowledge base to the database of the software agent during transactions. The data values are stored in parts-to-be-purchased table of SupplySelect. The parts-to-be-purchased form consists of a drop down list that shows available parts. The 10 parts in the drop down list illustrate the part form as depicted in Figure 4.2.

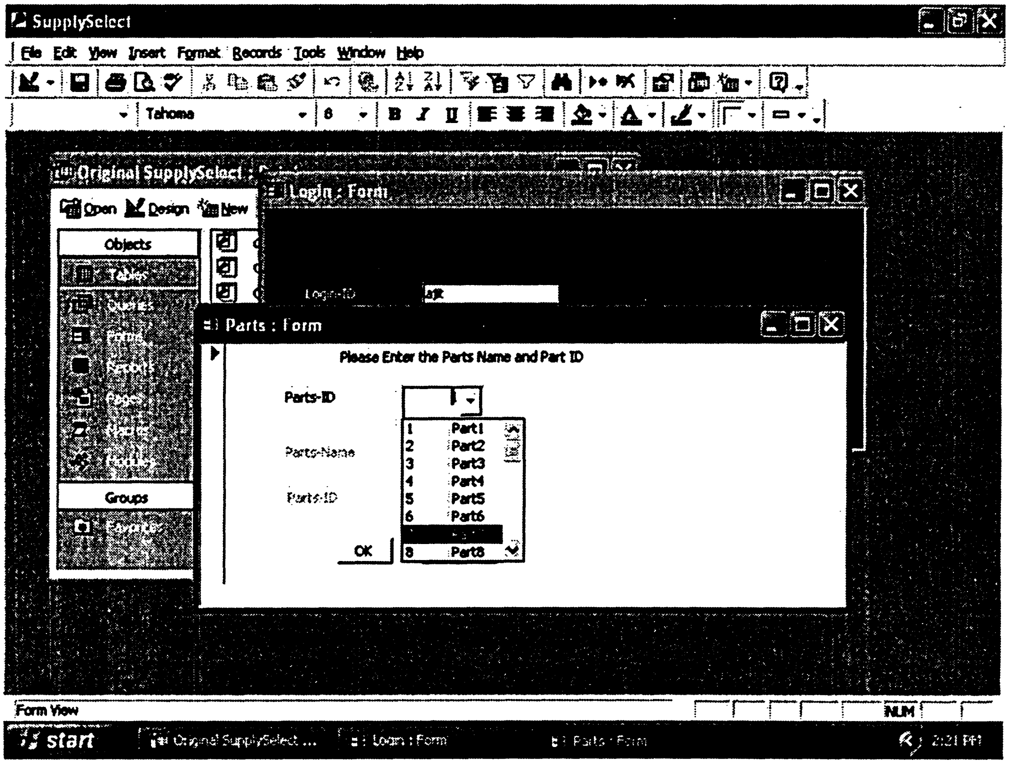


Figure 4.2 Parts Form

The form retrieves data from parts-to-be-purchased table shown in Table 4.2. It consists of two fields: parts name and parts identification codes. The parts are identified by their identification codes and they should satisfy the purchasing needs of the buyer's organization. After selection of a part and clicking OK, the system moves to a new window that is known as the attribute form.

Table 4.2 Parts Table

Parts-Name	Parts-ID
Part 1	001
Part 2	002
Part 3	003
Part 4	004
Part 5	005
Part 6	006
Part 7	007
Part 8	008
Part 9	009
Part 10	010

4.3.3 Attribute Form

The attribute form indicates various attributes that the buyer uses for evaluating suppliers. SupplySelect considers four major attributes: price of parts to be purchased, service performance of the supplier, quality of parts supplied and technology-in-use by the supplier. Figure 4.3 depicts the detailed structure of the attribute form. Each attribute has an option button. Buyers may request for one, two or all the listed attributes for purchase of the specified product. SupplySelect provides the flexibility of selecting one or more attributes for the selection process. The attribute form stores data in the attribute table. Here, suppliers that are willing to sell the specified parts are listed on top right hand corner of the window.

For illustration, three suppliers are indicated. Additional suppliers are added in the database and this will be reflected in the parts form. A supplier's information is stored in the supplier table. The structure of the supplier table and attribute table is shown in Table 4.3 and Table 4.4 respectively.

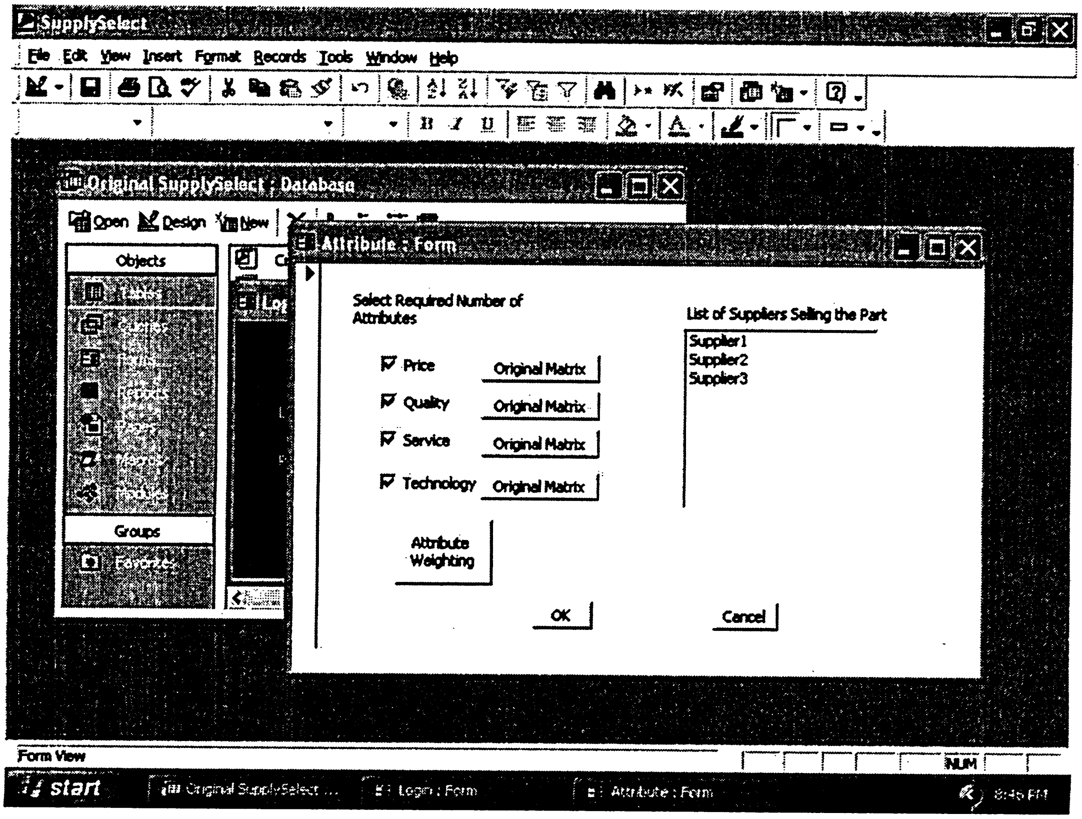


Figure 4.3 Attribute Form

Table 4.3 Suppliers Table

Suppliers' Name	Suppliers Code
User 1	***
User 2	***
User 3	****
User 4	***
User 5	***

Table 4.4 Attributes Table

Suppliers' Name	Parts ID	Price of the Part (In $s)	Service Performance	Quality Rating	Technology-in-use
User 1	001	1000	A	A	1
User 2	004	1574	B	D	2
User 3	005	2100	A	C	3
User 4	007	1470	C	B	3
User 5	002	1100	D	B	1

The attributes table consists of the supplier's name, parts and the supplier's responses to RFPs. The response consists of the supplier's quote for price, service, quality and technology-in-use. The service performance includes delivery date and time, quantity to be delivered and payment modes. Each buyer may have a different system of quality ratings. The database shows default quality and service performance ratings as A, B, C etc. Technology-in-use is rated numerically as 1, 2, 3...etc. Ratings do not affect the decision-making process. The attribute manager handles the data values for various attributes and updates the attributes table for every transaction. For example, if a new supplier put forward its responses then new data values will be generated and stored against the corresponding supplier's name or identification code. The supplier's table consists of two fields: supplier's name and supplier's code. The login data manager assigns login identification codes to a supplier and buyer and handles suppliers and buyers database differently.

4.3.4 Original and Adjusted Matrix Forms for the Attribute Weighting

In the proposed approach, the attributes are weighted for each transaction. A buyer may not equally prefer all the attributes for a particular transaction. For example, a purchasing coordinator may select just one or two attributes to evaluate suppliers. He may select only price or price and service performance to rank the suppliers. The flexibility of choosing just one or two attributes to rank the supplier makes the process more efficient and practically justifiable. After the selection of the attributes, the buyer sets the priority of the attributes.

The process of obtaining the weight for each attribute is started by clicking on the command button starts each attribute labeled as attribute weighting. In this illustration, four attributes are considered for supplier selection. The additional attributes can be added and stored in the database of the system. The measurement scale by Saaty (1980) is used for pairwise comparisons of the attributes. The original matrix for the attribute weighting is depicted in Figure 4.4. As observed in the original matrix, price is very strongly preferred to service, strongly preferred to quality and very strongly to extremely prefer to technology-in-use. The buyer should be very critical in his decisions of numerical ratings as they affect the final scores of the suppliers. The overall weights for each attribute are depicted in Figure 4.5. The price, quality, service performance and technology have the overall weights of 0.524, 0.196, 0.108, and 0.172 respectively. Hence, the buyer prefers the price of a part to be purchased to all other attributes. In real life situations, a buyer prefers to deal with suppliers offering low price quotes. Quality is ranked second with the overall weight of 0.196. The service performance is ranked fourth with the score of 0.108.

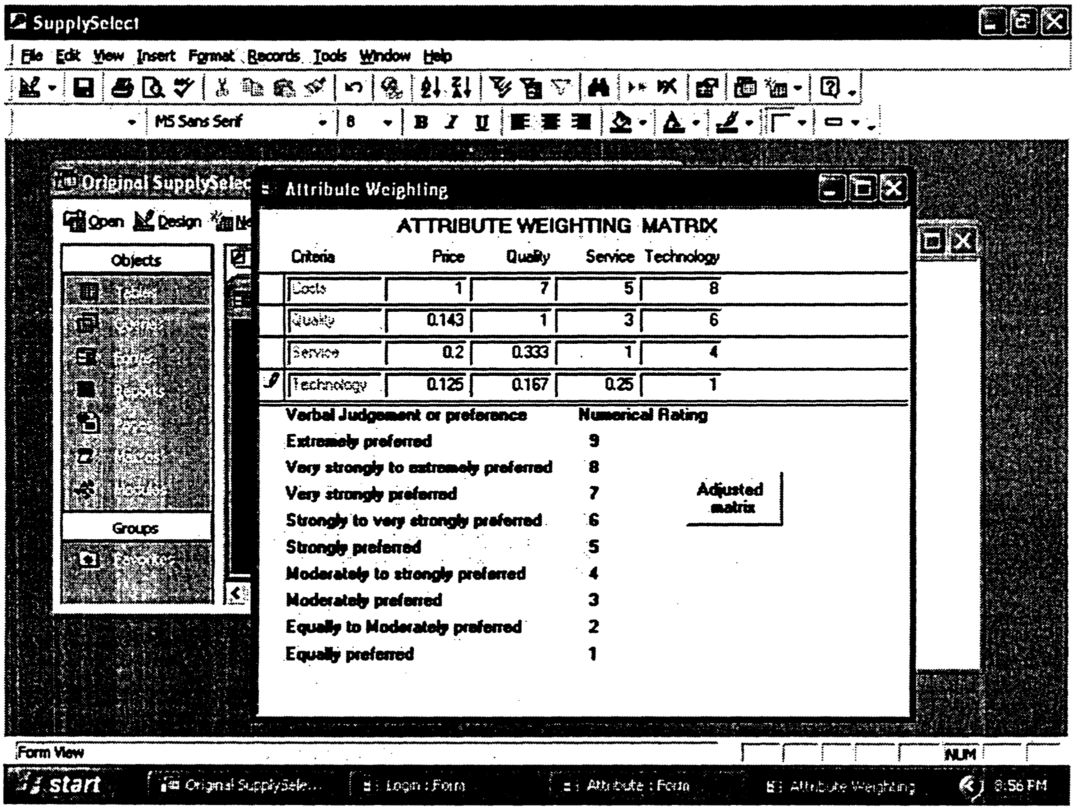


Figure 4.4 Original Matrix for the Attribute weighting

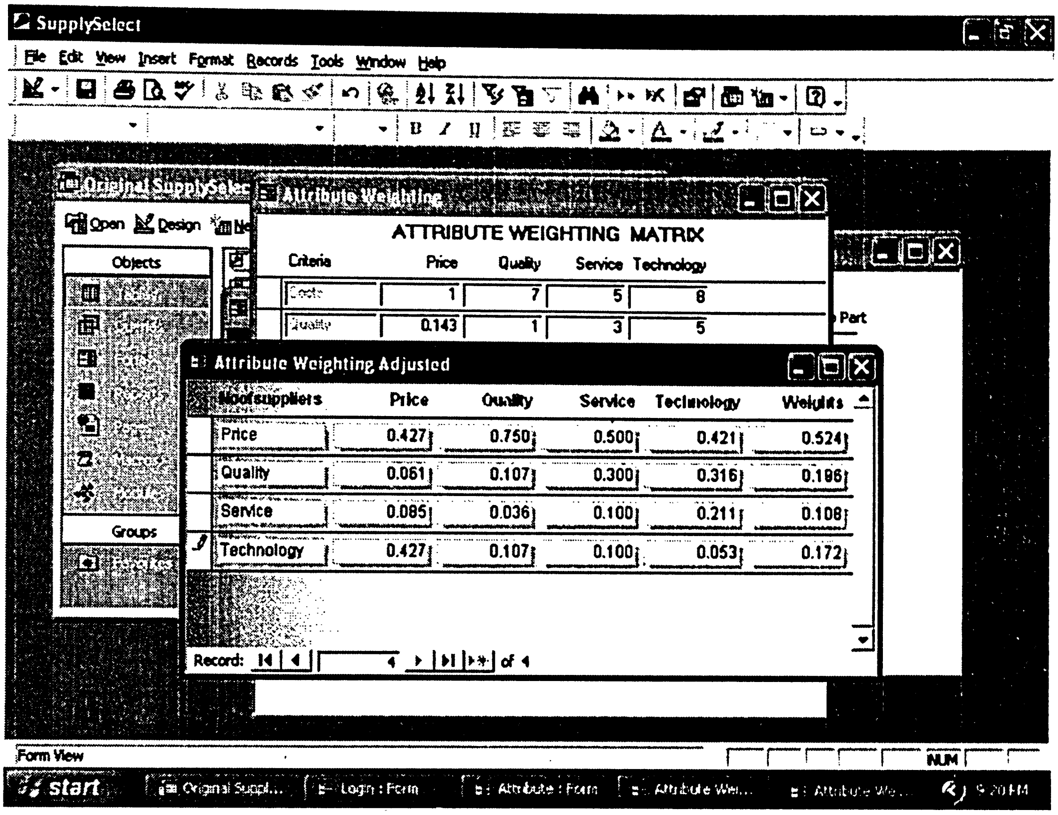


Figure 4.5 Adjusted Attribute Matrix for the Attribute Weighting

4.3.5 Original and Adjusted Matrix Forms for the Price Attribute

The decision-making process is based on an amalgamation of the additive value function and AHP. The individual score of a supplier is calculated for each attribute with the help of the original and adjusted matrix forms. The command buttons are created in front of each attribute as shown in the attribute form. The buttons are titled as original matrix and are activated once the buyer selects the attribute. A new window for the original matrix is created after clicking on the command button. The original matrix for the price criterion depicted in Figure 4.6.

Three suppliers are nominated for the evaluation and selection process. The default values in all the columns of the original matrix are 1. The measurement scale by Saaty is constructed just below the original matrix. It helps the buyer visualize the process. The diagonal elements are always 1. For illustration, the original price matrix is shown with numerical ratings in Figure 4.6.

The adjusted matrix is shown in Figure 4.7. The process is described in Chapter 3 by a numerical illustration. Supplier 1, Supplier 2 and Supplier 3 have individual scores of 0.525, 0.235 and 0.240 respectively.

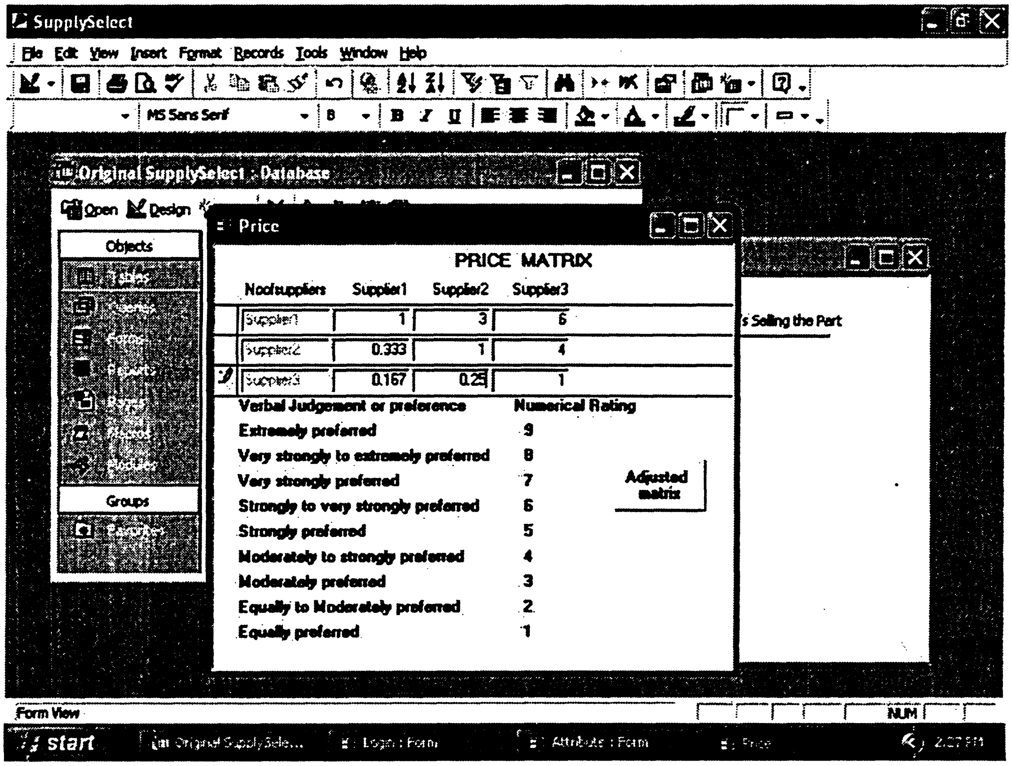


Figure 4.6 Original Matrix for the Price Attribute

The original and adjusted price matrices store data from the original and adjusted price tables in the agent's database. The table's structure resembles the original and adjusted price matrix forms at the front- end. The data values change for every transaction. These tables are meant for temporary storage of the calculated data. As soon as a new transaction starts, the tables remove old values and store the new ones. The structure of the tables is shown in Table 4.5 and Table 4.6.

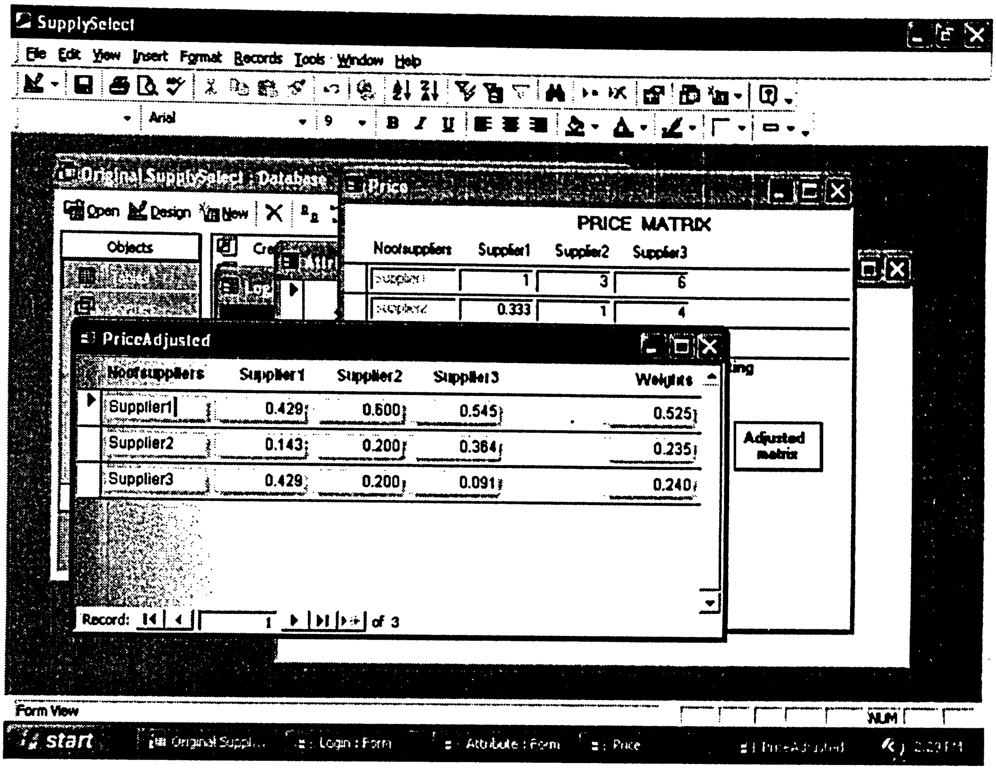


Figure 4.7 Adjusted Matrix for the Price Attribute

Table 4.5 Original Matrix Table for the Price Attribute

Number of Suppliers	Supplier 1	Supplier 2	Supplier 3
Supplier 1	1	3	6
Supplier 2	0.333	1	4
Supplier 3	0.167	0.250	1

Table 4.6 Adjusted Matrix Table for the Price Attribute

Number of Suppliers	Supplier 1	Supplier 2	Supplier 3	Scores
Supplier 1	0.429	0.600	0.545	0.525
Supplier 2	0.143	0.200	0.364	0.235
Supplier 3	0.429	0.200	0.091	0.240

4.3.6 Original and Adjusted Matrix Forms for the Quality Attribute

The quality of the parts to be purchased is a critical factor for supplier selection. Buyers may have their own methods of rating quality performance. In the proposed system, the suppliers are rated as A, B, C...etc and the ratings are stored in the supplier table. The original matrix for quality comparing suppliers with respect to attribute is shown in Figure 4.8. The original and adjusted matrices for quality store data in original and adjusted quality tables. In this case, supplier 1 is moderately preferred to supplier 2 and moderately to strongly prefer to supplier 3; and supplier 2 is strongly to very strongly preferred to supplier 3. The adjusted matrix is shown in Figure 4.9. Supplier 1, supplier 2 and supplier 3 have obtained scores of 0.464, 0.296 and 0.240, respectively. Hence from the calculations, it is clear that supplier 1 is preferred to supplier 2 and supplier 3.

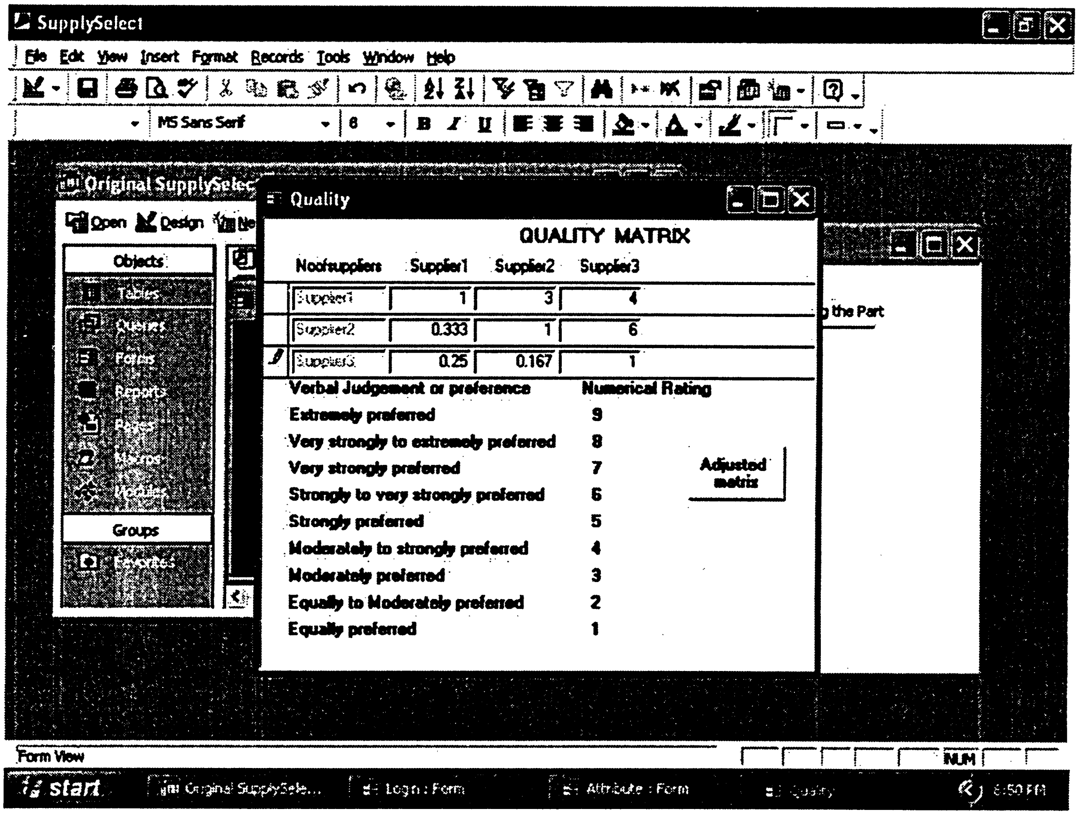


Figure 4.8 Original Matrix for the Quality Attribute

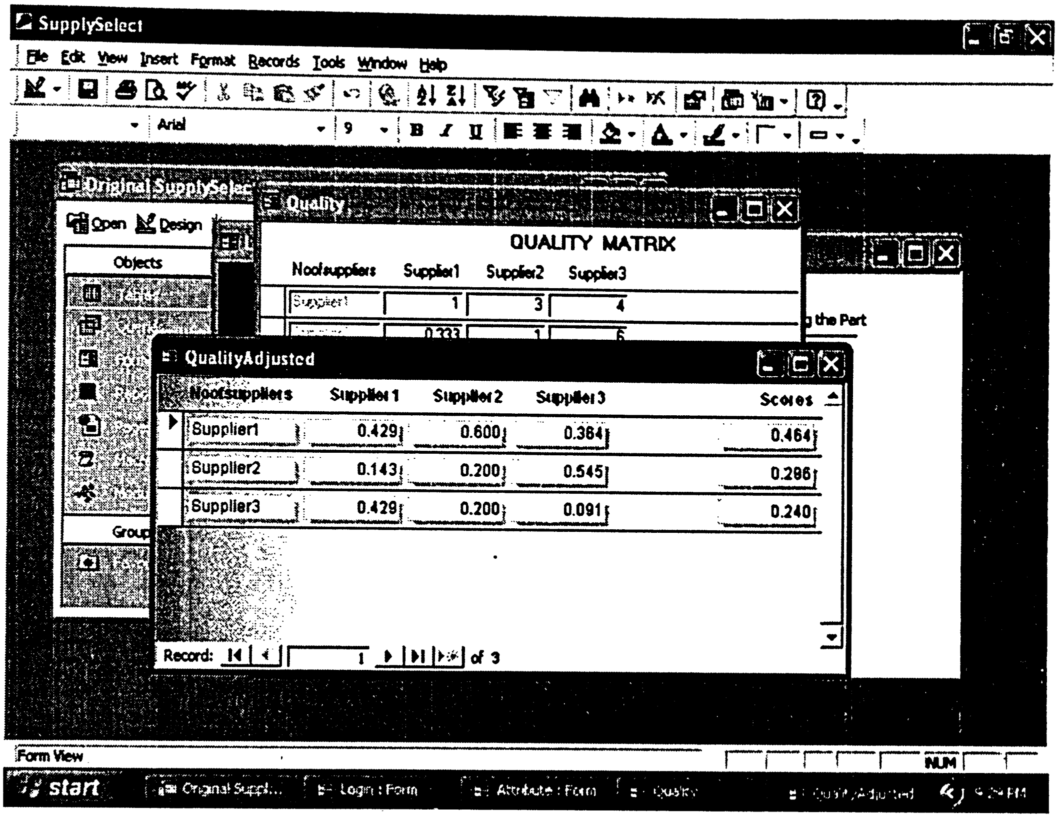


Figure 4.9 Adjusted Matrix for the Quality Attribute

4.3.7 Original and Adjusted Matrix Forms for the Service Attribute

The service includes factors like on-time delivery, quantity of material delivered, payment terms etc. A buyer may include one or all factors for evaluation. Firms like Chalmers Suspensions International Inc. have their own rating systems for the service performance for their suppliers. The original matrix for the service is shown in Figure 4.10. The comparisons are illustrated by various numerical ratings as shown in the original matrix. The buyer moderately-to-strongly prefers supplier 2 to supplier 1 for service. Similarly supplier 2 is preferred strongly to supplier 3. The rest of the elements are filled in similar fashion as shown in Figure 4.10. The final scores of the suppliers for service are obtained by clicking on the adjusted matrix and are shown in Figure 4.11. As seen in Figure 4.7, supplier 1, supplier 2 and supplier 3 have obtained the individual scores of 0.259, 0.509, and 0.231 respectively. Hence supplier 2 is preferred to supplier 1 and supplier 3 in terms of service performance

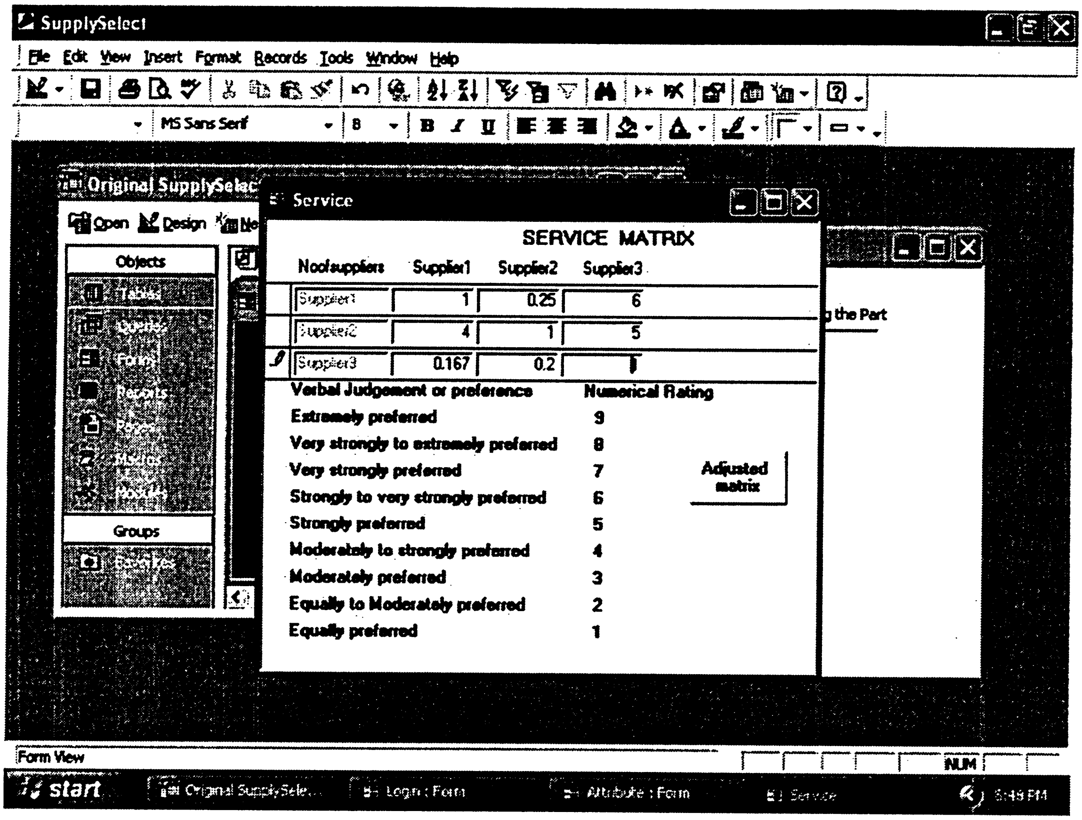
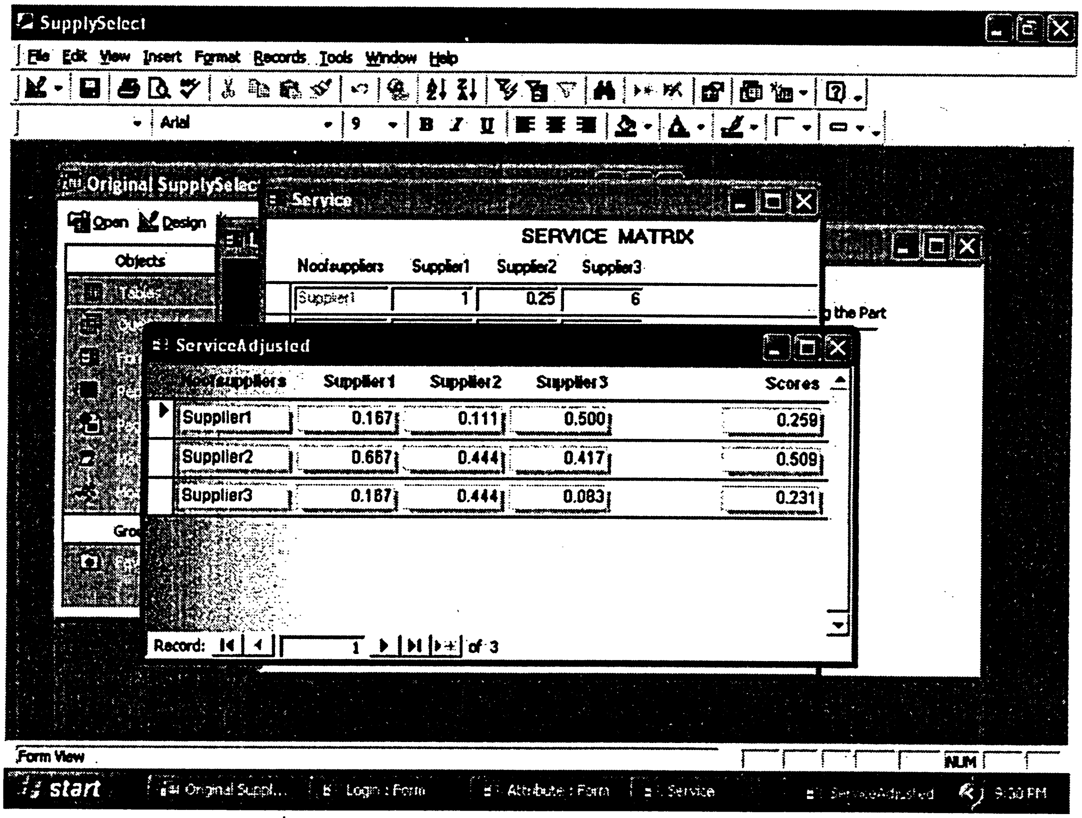


Figure 4.10 and 4.11 Original and Adjusted Matrix for the Service Attribute



4.3.8 Original and Adjusted Matrix Forms for the Technology Attribute

The technology of the supplier should be compatible with that of the buyer. The similarity of technologies are recognized by numerical values such as 1, 2, 3 etc. Hence the data is stored as a numerical value in the agent's database. The original and adjusted matrix forms for the technology-in-use attribute are depicted in Figures 4.12 and 4.13 respectively. The data is accessed from the original and adjusted matrix tables. It is observed that supplier 1 supplier 2 and supplier 3 has obtained the individual scores of 0.377, 0.379 and 0.244 respectively. Hence, supplier 2 is preferred to supplier 1 and supplier 3 for the technology-in-use attribute. In this way, a buyer scores the three suppliers for all the attributes. For a particular transaction, the individual scores of the supplier for each attribute are stored in the corresponding databases.

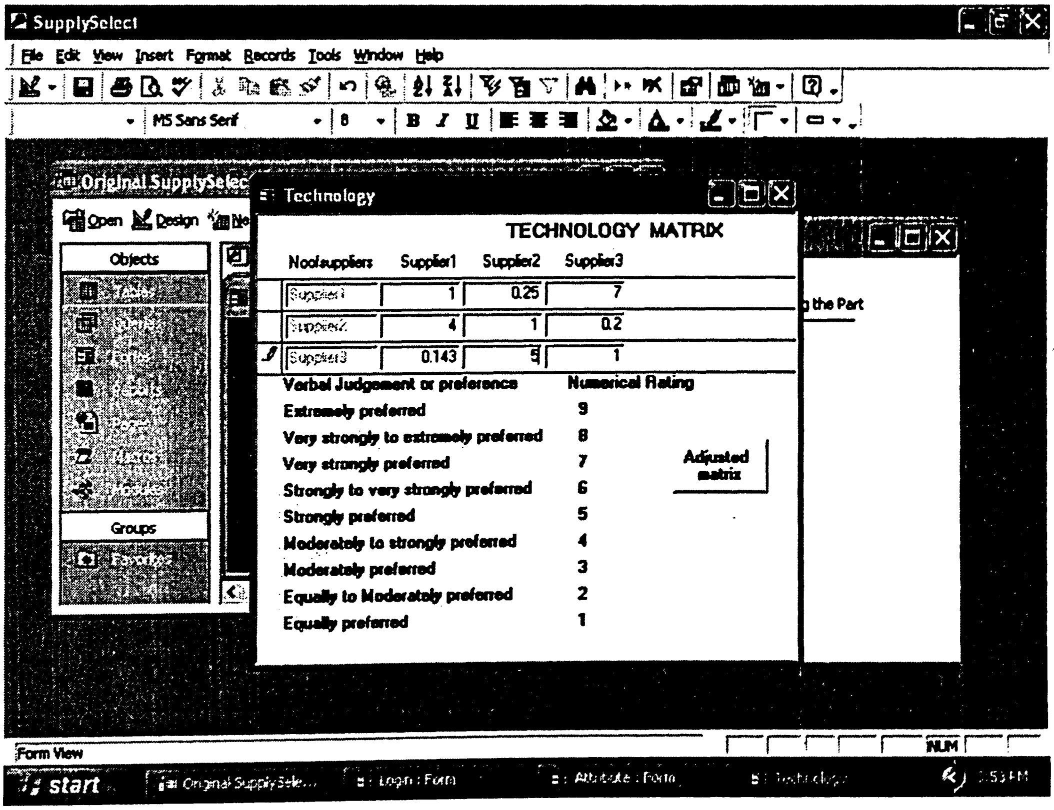


Figure 4.12 Original Matrix for the Technology-in-use Attribute

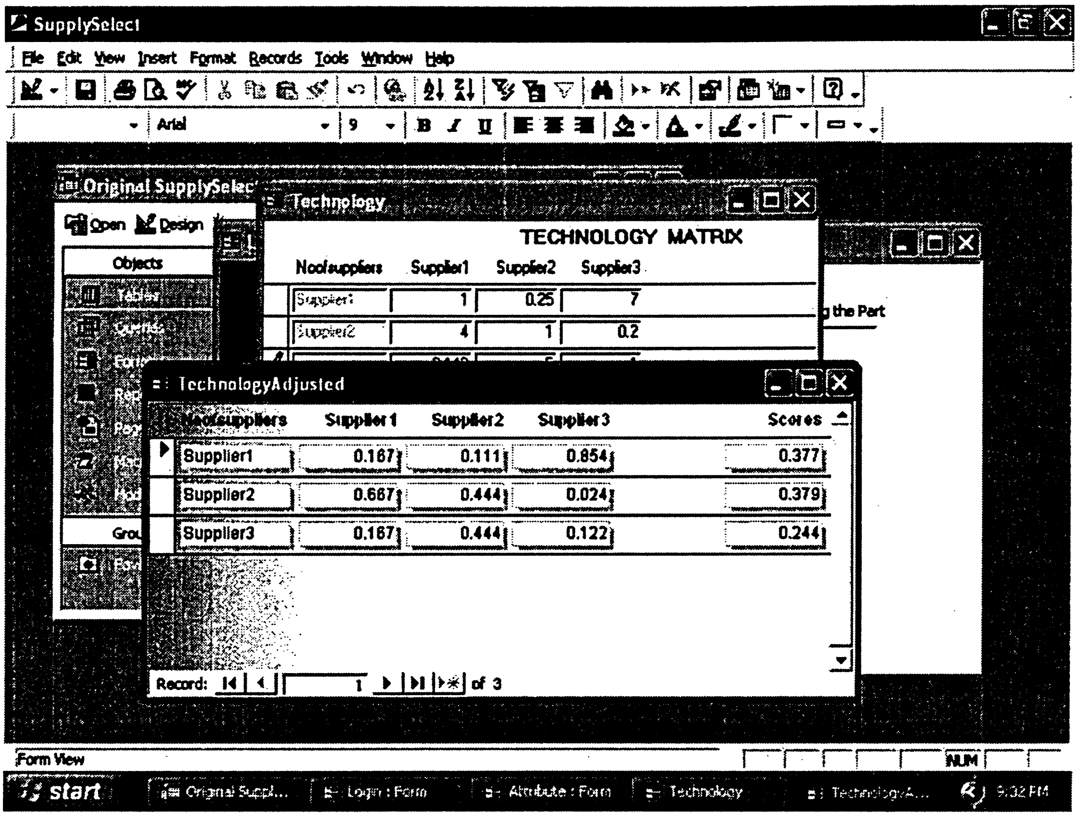


Figure 4.13 Adjusted Matrix for the Technology-in-use Attribute

4.3.9 Form for the Total Score of Suppliers

The total score of each supplier is the last step in the selection process and it is significant because it helps a buyer visualize the selection process and the best supplier. In real life situations, a buyer wants to keep long-term relationships with the suppliers. The total score helps the buyer analyze to choose a long-term supplier. The total score of each supplier is calculated by the summation of the product of the individual score of that supplier in terms of attribute and the weight of the corresponding attribute. The total score indicates the overall ranking of each supplier with respect to all attributes and is depicted in Figure 4.14. The total score of a supplier is obtained by clicking on the "OK" button. The total scores of supplier 1, supplier 2 and supplier 3 are obtained as 0.371, 0.348 and 0.281 respectively. Supplier 1 has the highest total score of 0.371 and hence the buyer selects it as the best supplier.

The supplier selection system provides a buyer with the individual scores the suppliers for each attribute and total scores of each supplier. The two different types of scores help in better understanding of the selection process. In the Section 4.5, a case study conducted at Chalmers Suspension International Inc is presented to show the practical implications of the system.

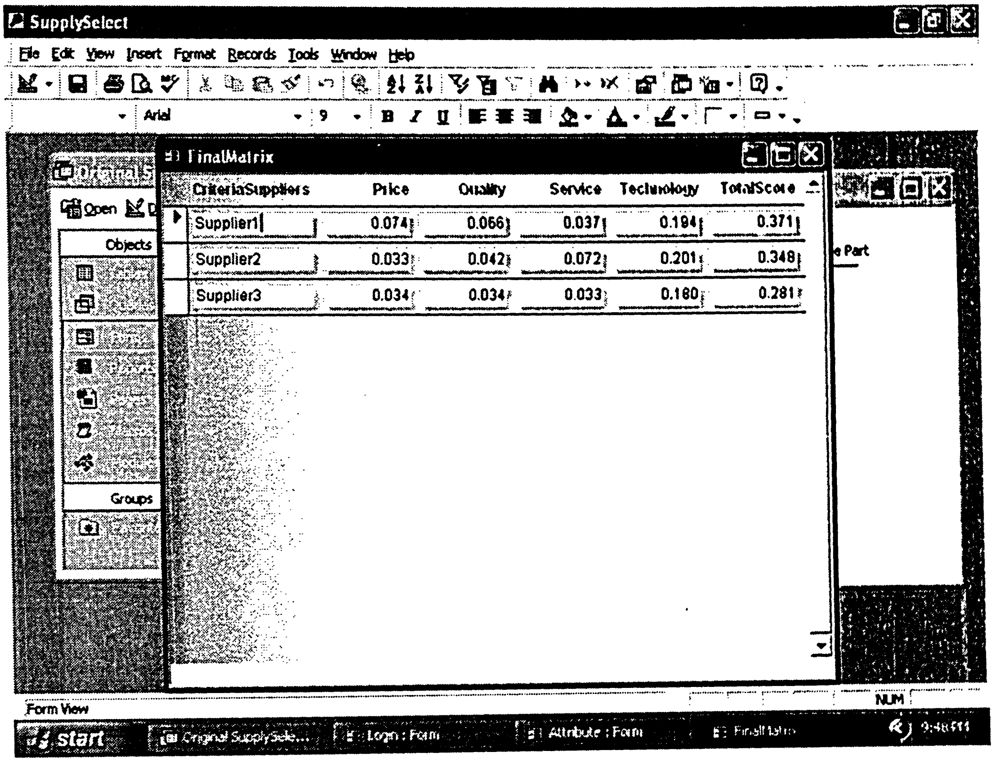


Figure 4.14 Total Score of Suppliers

4.3.10 Performance Evaluation of SupplySelect

The performance of SupplySelect is evaluated in terms of the execution time. The execution time means the time required by the system to complete a transaction. Firstly, the system is examined with respect to the number of suppliers. The numbers of suppliers are gradually increased from 2 to 10 and the execution time is noted for every transaction. The performance is depicted graphically in Figure 4.15. It can be observed that the execution time is proportional to the number of suppliers.

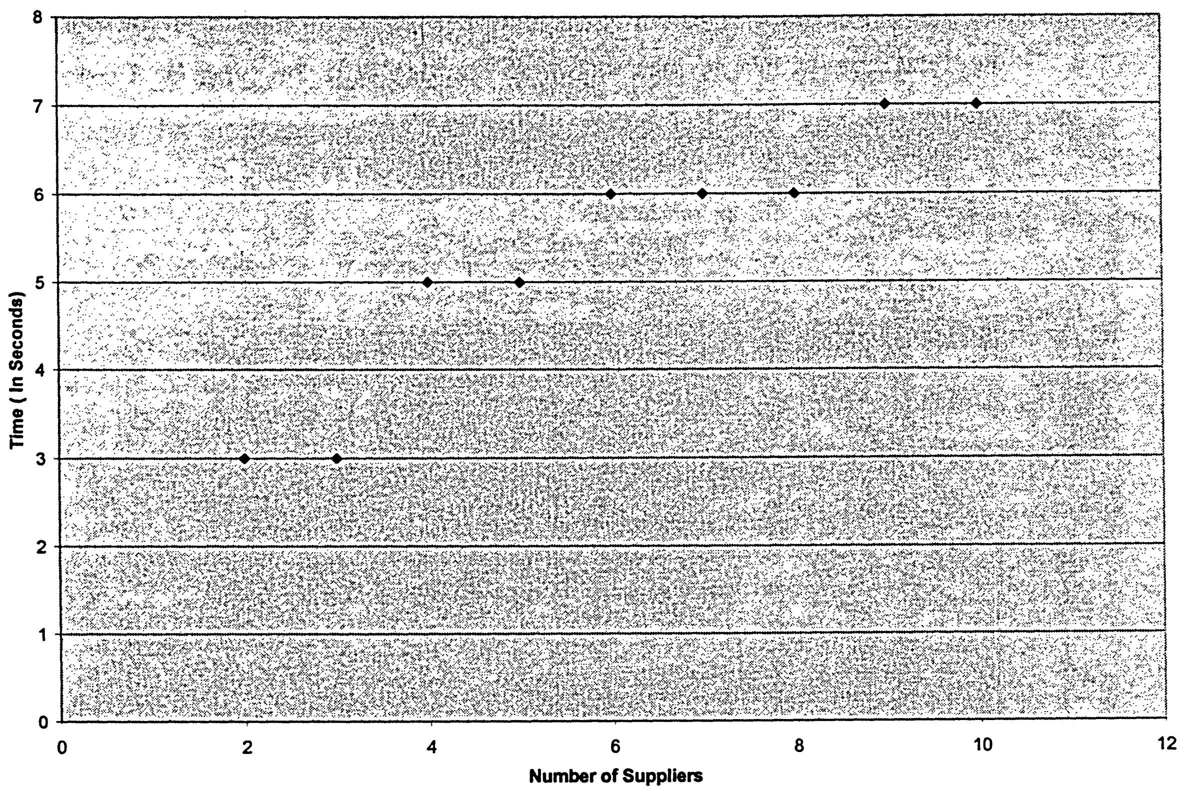


Figure 4.15 Performance of SupplySelect in terms of the Number of Suppliers

Secondly, the system is evaluated with respect to the number of attributes. The attributes are gradually increased from 1 to 10 and the execution time is noted for every transaction. The performance is graphically depicted in Figure 4.16. From the graph, it is clear that the execution time is proportional to the number of attributes. However, the increments in the time are not significant as compare to the number of attributes or suppliers.

4.4 Comparisons of the Proposed System and Other Approaches

This section compares some existing supplier selection systems with the proposed approach. Vokukra et al. (1996) discuss a prototype expert system for supplier evaluation and selection. It is noticeable that the design of the expert system includes many aspects of the procurement process. Bichler et al. (2001) describes the ABSolute framework that provides buyer-side decision support for electronic sourcing. The framework is based on the WORA technique (Weight Assessment based on Ordinal Ranking of the Attributes). The proposed system is based on the AHP for assessing the individual scores of suppliers and weights of attribute. The AHP provides a structured approach for determining scores and weights. Most of the work has been carried out on negotiation between buyers and suppliers instead of systematic evaluation and selection of suppliers. The proposed supplier selection system works in conjunction with the negotiation support module and systematic supplier valuation and selection is integrated with the negotiation process.

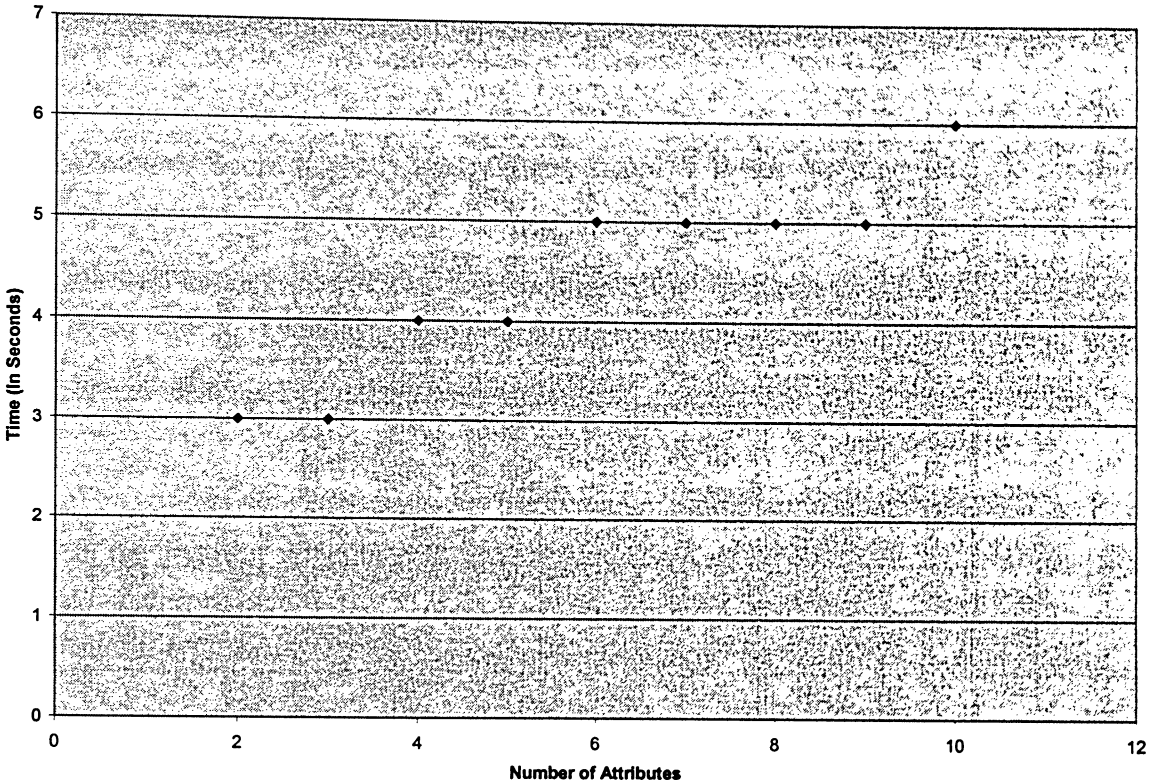


Figure 4 16 Performance of SupplySelect in terms of the Number of Attributes

4.5 A Case study at Chalmers Suspensions International Inc.

4.5.1 Introduction

A case study is conducted at Chalmers Suspensions International Inc. (Chalmers) to test the practical implications of the design and in particular the supplier selection system. Being a manufacturing firm, Chalmers is an appropriate industry to test practical implication of the proposed EM and the supplier selection system. The information is collected about the firm and its procurement process, for the comparison of present and proposed method of procurement and supplier selection. The experimentation indicates that the implementation of the system depends on a company's previous purchasing process.

4.5.2 Chalmers Suspensions International Inc.

Chalmers Suspensions International Inc. was established in 1971. Since its inception, Chalmers has successfully established itself as an innovative company with an excellent product line designed to meet the industry need for a unique suspension system with characteristics aimed for providing excellent performance and value. Over the past quarter century, Chalmers has experienced outstanding growth in truck and trailer markets. Chalmers positive reputation for its suspensions is based on advantages such as:

a) Lightweight,
b) High stability,
c) Excellent articulation,
d) Smooth ride, and
e) Full equalization and minimum maintenance.

As the reputation of Chalmers grew so did the demand. The Chalmers growth allowed it to penetrate into major truck manufacturers including Freightliner, Mercedes-Benz, Kenworth, Peterbilt, Volvo, GM, Mack, Navistar, and all major fire trucking and utility chasis manufacturers throughout the North America. Furthermore, Chalmers has been successful in entering overseas markets such as Middle East, Australia and New Zealand. Chalmers had proven itself to be a market leader for Dump, Van, Tank, Refuse, Logging, Sweepers, and Coaches. Chalmers' major strengths are not limited to its product line. Chalmers' dedication to quality, state-of-art technology, and engineering coupled with extensive testing and emphasis on research and development are way of life at Chalmers.

Theses factors, in conjunction with a team oriented group of individuals who are totally dedicated to the overall goal of providing top quality of product and a strong and dedicated emphasis on providing top class customer service, truly make Chalmers a leader in the suspension industry.

Chalmers is a QS 9000 registered company. It provides innovative solutions, quality products and exceptional services on a cost competitive basis. Chalmers deals mainly with suspensions products such as 700 series truck suspensions, 800 series tandem truck suspensions and 1000 single axle truck suspensions. It also deals with trouble shooting and replacements problems. Chalmers is located at Mississauga, Ontario.

4.5.3 Present Method of Procurement

The purchasing coordinator is responsible for the purchasing function of all direct material. He/She has the authority to qualify, disqualify and requalify any supplier. The present purchasing process consists of following steps:

a) The purchasing coordinator identifies the purchasing needs of the various departments of the company either by specialized software called as "Visual Manufacturing", which reflects information from various departments or by contacting the department heads of the company. The departments of the company are interlinked with each other through the software.

b) The purchasing coordinator puts forward RFPs to suppliers either by fax or through request forms.

c) The existing suppliers who have consistently maintained quality supplies in the past are included in the list of approved suppliers.

d) Before open orders are placed on a new supplier, its supplies are sample validated by the quality assurance department. Only those suppliers who qualify on quality requirements are classified as approved suppliers.

e) It is ensured that the purchasing data, including drawings and relevant standards are furnished to the suppliers.

f) The type and extent of the control exercised over the suppliers is either by providing relevant purchasing data or by conducting visits to suppliers or by informing suppliers about specific requirements of the products.
g) The exercise is carried out depending upon the product ordered. The outcome of the inspection and test results are also communicated to the supplier concerned in case the product does not meet the specified requirements.
h) The suppliers are ranked on the three attributes namely price, quality performance, and delivery performance. The supplier selection process is explained in detail in the next subsection.
i) Whenever the parts or components are to inspect or tested at the supplier's end, verification arrangements and method of product release shall be specified in the purchasing document or through a separate intimation to the supplier concerned.

The next sub section describes the supplier selection process in detail. The decision-making is based on verbal judgments and cost-based approaches.

4.5.4 Present Method of Supplier Selection

The present method of the supplier selection is a cost-based approach. The suppliers are ranked on three attributes namely price of part-to-be-purchased, quality of the part and delivery performance of the supplier. The purchasing coordinator analyzes the price quotes. There is no specific methodology available for systematic selection of suppliers for price. The supplier with low price quote is preferred to one with high price quote. In some situations, other attributes are also considered and a best supplier is selected. This method of supplier selection for price is same for existing and new suppliers. The suppliers are ranked on the quality performance on a basis of interpretation scale depicted in Table 4.7. The numerical values indicate the quality cost performance index (QPI). Suppliers with an index value of between 1.000 and 1.009 are considered excellent. Suppliers with an index value of between 1.010 and 1.039 are considered good, and so on. The method of QPI holds true for existing approved suppliers. A sample QPI is calculated as shown in Table 4.8. The approximate value of QPI for the data is 1.006. Hence, the quality performance of supplier is excellent.

There is no specific methodology available for the quality rating of new suppliers. New suppliers with low price quotes are preferred for selection. The quality assurance department validates the samples of the part to be purchased. Chalmers bears the tooling cost of a new supplier. If the quality requirements are fulfilled, then orders are placed to the new supplier. New suppliers are included in the list of approved suppliers after analysis of service performance

Table 4.7 Supplier Interpretations for Quality

Index	Interpretation
1.000 – 1.009	Excellent
1.010 – 1.039	Good
1.040 – 1.069	Fair
1.070 – 1.099	Poor
1.100 and plus	Immediate Corrective Action Required

Table 4.8 A Sample Supplier's Quality Rating

Total Purchase Cost of Year 2002	**$ 1661459.00**
Total Costs of Parts Rejected for Year 2002 (L)	**$ 8624.97**
Number of PAR's raised (A)	56.00
Administrative time for a PAR (including raising, sending to supplier and following up) (B)	15 minutes or 0.25 Hours
Labor cost + Overheads per hour	$ 50.00
Administrative Cost for PAR's (including raising, sending to vendor and following up) (X=A*B*C)	**$ 700.00**
Total Number of Item Rejected (D)	41.00
Inspection time per item (E)	10 Minutes or 0.17 Hours
Total Inspection Cost (Y =D*E*C)	**$ 348.50**
Supplier Quality Cost (Z = L+X+Y)	**$ 9673.47**
$QualityCostPerformance = \frac{(VendorQualityCost + TotalPurchaseCost)}{TotalPurchaseCost}$	**1.006**

The suppliers are ranked for delivery performance based on delivery time and date. The purchasing coordinator, through Visual Manufacturing software, accesses the delivery time and date of the supplier. The ratings for the delivery performance are depicted in Table 4.9. The delivery performance report is generated every month and indicated to each supplier. The method of delivery performance is used for existing suppliers. There is no specific methodology available for new suppliers.

Table 4.9 Rating for Delivery Performance

Rating	Details
A	Always on Time (Excellent Performance)
B	1 to 3 days late (Need Improvement in meeting delivery dates)
C	Late by 4 days or over (Corrective Action Required)

To summarize, Chalmers ranks the supplier on three attributes discussed above. The methodologies of the supplier selection are based on judgments and cost-based approaches. There is no specific methodology available for new suppliers. The proposed method of electronic procurement and supplier selection that helps Chalmers is discussed in detail in the next subsection.

4.5.5 Proposed Method of Electronic Procurement

The proposed design described in Chapter 3 is systematically applied to Chalmers as discussed below. The purchasing coordinator registers its company in the proposed business-to-business EM through registration forms available on the EM. The purchasing coordinator puts forward a RFP after identifying his company's purchasing needs. Purchasing needs are identified by Visual Manufacturing software, which interconnects the various departments of the firm. The purchaser agent electronically transmits the RFP to suppliers' agents.

The Chalmers agent in its task-oriented domain *(TOD)* $_{ch}$ is defined as below.

$$(TOD)_{ch} = (T_{ch}, A_{ch}, C_{ch})$$

Where,

a) T_{ch} is the set of task list of the Chalmers agent. Here, T_{ch} = *{Quote generation, Transmission of messages, evaluation and selection}.*
b) A_{ch} is the identification of the Chalmers agent.
c) C_{ch} is a monotonic cost function of the Chalmers agent. It is the cost of executing all the tasks in the task set.

The efficiency of the purchaser agent is measured in terms of two parameters: The completion of tasks within time constraints and cost of executing the tasks. It is clearly indicated that the efficiency is inverse proportional to the time taken and cost. The efficiency of the agent helps the purchasing coordinator analyse the weakness of the transaction and keeps check on the functionality of the agent. The efficiency of the Chalmers agent is defined as shown below:

$$E_{ch} = \frac{1}{1 + \left| \frac{O_{dch} - O}{O_{dch}} \right|}$$

Where,

a) O_{dch} is the desired output of the Chalmers agent
b) O is the actual output of the Chalmers agent

Registered suppliers respond to the request through their quotes. Each supplier has its agent. The suppliers' agents are also defined in task-oriented domains. The task-oriented domain of a supplier is defined below. For example, Custom engineering and Janach metals are suppliers to Chalmers. The task-oriented domain for a supplier agent is a tuple of three parameters namely the task set, agent's identification and a cost function.

$$(TOD)_s = Tuple\ (T_s, A_s, C_s)$$

Where,

a) T_s is the set of tasks of the supplier agent. Here, the T_s = *{Responds to RFQ, Transmission of messages, Negotiation}*

b) A_s denotes a supplier agent.

c) C_s is the cost of executing the tasks in the task list within time constraints.

The efficiency of a supplier agent is defined as below.

$$E_s = \frac{1}{1 + \left| \frac{O_{ds} - O}{O_{ds}} \right|}$$

Where,

c) O_{ds} is the desired output of the supplier agent.

d) O is the actual output of the supplier agent

The message engine transmits messages between the purchaser agent and suppliers' agents. The format of a message is described in Chapter 3. The Chalmers agent and suppliers' agents negotiate according to strategy in the negotiation support module. The Chalmers agent transmits responses to purchasing coordinator. If purchasing coordinator is satisfied by the responses, then the responses are evaluated in the decesion engine.

The transactions among agents and users are stored in the storage of transaction for future reference. The agents access the knowledge base for more information. The purchasing coordinator, through fax or email, passes on information and relevant purchasing data to the supplier. Registered buyers and suppliers are eligible to access the knowledge base of the system to maximize their profits. The knowledge base is updated periodically. Four major attributes are considered for evaluation purpose namely price, quality performance, service performance and technology-in-use for supplier selection.

The proposed method of the supplier selection is discussed in detail in the next subsection. The decision engine helps the purchasing coordinator for the selection purpose. The electronic procurement is completed after the selection of the best supplier. The purchasing coordinator accepts the response of the best supplier. The proposed method is better as it automates the supplier selection process and quotes generation and hence reduces transaction cost and time.

4.5.6 Proposed Method of Supplier Selection

The software agent SupplySelect carries out the supplier selection in the proposal evaluation engine. The suppliers are ranked on four major attributes namely price of part-to-be-purchased, service performance of the supplier, quality performance, and technology-in-use by the supplier. The proposed method of supplier selection is unique in a way that the calculations of weights and scores are carried out by the AHP.

The purchasing coordinator not only visualizes the price quotes of the suppliers, but also carries out systematic evaluations based on price and other attributes by the help of the supplier selection system "SupplySelect". The sample calculations and evaluations based on price of part-to-be-purchased are shown in Section 4.2. This approach is valid for existing approved suppliers as well as new suppliers. The test for price indicates its flexibility of the proposed approach.

The quality ratings of the suppliers are stored in software agent's database. New suppliers are included for quality ranking after supplies are sample validated. The third attribute is the service performance of the suppliers. Service performance includes delivery time and date and payments terms. Unlike Chalmers, the system ranks suppliers on three sub-attributes for service performance.

The final attribute in the proposed method is the technology used by the users. As mentioned, the technology of the supplier should be compatible with that of buyer. The technology-in-use should be included as it reduces the tooling cost of the company especially for the new suppliers. Chalmers may suggest reworking of the parts and revise the design to incorporate the new suppliers in the list of approved suppliers. The proposed method of supplier selection provides flexibility in the selection process and can be utilized for existing as well as new suppliers.

4.5.7 Suggestions by the Purchasing Coordinator

The purchasing coordinator has test run the supplier selection system, SupplySelect, several times in the firm. The suggestions by the purchasing coordinator are as follows:

a) The individual quality and service rating systems should be incorporated into the supplier selection system.
b) The purchasing coordinator suggests to link the cost based approach and AHP for supplier evaluation and selection.
c) The purchasing coordinator requests separate supplier selection system for his company due to very specific purchasing needs.
d) Overall performance of the system is considered satisfactory.

Chapter 5 Conclusions and Future Work

In this thesis, a novel design of a web-based multiagent system for electronic procurement that integrates an agent-mediated negotiation support and a decision support system for supplier evaluation and selection is presented. A new system is proposed where buyers and suppliers not only avail themselves of the various opportunities of a business-to-business marketplace but also utilize the negotiation support and decision support system, making the procurement process efficient and productive, by reducing transaction cost and time. The integration of approaches actively improves the procurement process. The case study at Chalmers Suspension International Inc. illustrates practical implications of the proposed design and, in particular, the software agent SupplySelect.

A detailed literature review is conducted on the topics that include electronic marketplaces and agent technologies in supply chain management in Chapter 2. Chapter 3 describes the design of a business-to-business electronic marketplace and includes the details of various components of the proposed electronic marketplace. The proposed design is compared with existing approaches in Chapter 3. In Chapter 4, a supplier selection system, SupplySelect, is implemented, and a case study conducted at Chalmers Suspension International Inc. is described. Chapter 4 also indicates the practical implications of the proposed design.

5.1 Contributions

The main contributions of the research contained in this thesis are as follows:

a) A novel design of a business-to-business electronic marketplace that integrates negotiation support and decision support is proposed. The details of various components of the proposed electronic marketplace are described. The proposed design is compared with the existing approaches.
b) A method of negotiation, based on task-oriented multiple agents, is included in the proposed approach.

c) A supplier selection system, SupplySelect, is developed and implemented for the systematic supplier evaluation and selection.
d) A real-world case study is conducted at Chalmers Suspensions International Inc. to illustrate practical implications of the proposed approach.

5.2 Future Work

This research has covered relatively new ground in the procurement area that is being created by developments in information technology and revolutionary changes in business models, brought about by the Internet. The research describes how supply chain management, in particular, procurement, can be examined by analyzing different types of relationships within different EM categories. The following research questions, which should be empirically tested in the future research, are suggested:

a) Implementation and testing of the proposed design.
b) Implementation and testing of the negotiation support system.
c) Beyond the perspective of supply chain management, the design of EM depends on the different EM categories, and firms.
d) The integration of negotiation and decision support systems within different EM categories.

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