BUILDING TRUST FOR SERVICE ASSESSMENT IN INTERNET-ENABLED COLLABORATIVE PRODUCT DESIGN & REALIZATION ENVIRONMENTS

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Reducing costs, increasing speed and leveraging the intelligence of partners involved during product design processes are important benefits of Internet-enabled collaborative product design and realization environments. The options for cost-effective product design, re-design or improvement are at their peak during the early stages of the design process and designers can collaborate with suppliers, manufacturers and other relevant contributors to acquire a better understanding of associated costs and product viability. Collaboration is by no means a new paradigm. However, companies have found distrust of collaborative partners to be the most intractable obstacle to collaborative commerce and Internet-enabled business especially in intellectual property environments, which handle propriety data on a constant basis. This problem is also reinforced in collaborative environments that are distributed in nature. Thus trust is the main driver or enabler of successful collaborative efforts or transactions in Internet-enabled product design environments.

Focus is on analyzing the problem of 'trust for services' in distributed collaborative service provider assessment and selection, concentrating on characteristics specific to electronic product design (e-Design) environments. Current tools for such collaborative partner/provider assessment are inadequate or non-existent and researching network, user, communication and service trust problems, which hinder the growth and acceptance of true collaboration in product design, can foster new frontiers in manufacturing, business and technology. Trust and its associated issues within the context of a secure Internet-enabled product design & realization platform is a multifaceted and complex problem, which demands a strategic approach crossing disciplinary boundaries. A Design Environment Trust Service (DETS) framework is proposed to incorporate trust for services in product design environments based on client specified (or default) criteria. This involves the analysis of validated network (objective) data and non-network (subjective) data and the use of Multi Criteria Decision Making (MCDM) methodology for the selection of the most efficient service provision alternative through the minimization of distance from a specified ideal point and interpreted as a Dynamic (Design) Trust Index (DTI) or rank. Hence, the service requestor is provided with a quantifiable degree of belief to mitigate information asymmetry and enable knowledgeable decision-making regarding trustworthy service provision in a distributed environment.

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1.0 INTRODUCTION

Electronic business today plays a major role in the world's economy. According to Phan, Forrester Research estimates that, by 2003, the value of electronic commerce of US and Europe would reach US$ 3 trillion [1] ****. However, electronic business is still plagued with a history of distrust. In the year 2000, a Forrester survey also found that 51% of companies would not do business with parties they do not trust over the Internet [2].

As the Internet develops and matures, its success will largely depend on gaining and maintaining the trust of its visitors [3]. Also, as enterprises become more reliant on e-Commerce and e-Business applications, they quickly realize that the open nature of the Internet can result in exposure of sensitive data, critical applications, and network resources to risks, vulnerabilities and threats [4].

Thus, this thesis investigates *trust for service* issues in Internet-enabled collaborative product design and realization environments and presents a framework for an *enhanced* trust-support infrastructure.

**** Parenthetical references placed superior to the line of text refer to the bibliography.

1.1 COLLABORATION AND DISTRIBUTED ENVIRONMENTS

Collaboration is by no means, a new paradigm. The Computer Sciences Corporation [5], depicting an aerospace and defense industry perspective on collaborative product design, states that few companies have broken down the barriers preventing internal collaboration among functional areas and thus, there has been little success in collaborating across multiple companies. Collaboration – in particular collaboration around the design and development of new products – has not delivered the benefits companies expected.

A new collaboration approach is needed. Collaboration adopters express their disappointment at not seeing the projected savings in cost and time, and paradoxically may even see the product development times and costs grow. There are many reasons why product design collaboration has not delivered the anticipated benefits and in time past, the most frequently cited was information technology. However, the more complex issues around processes, participants and trustworthiness have still not been adequately addressed.

The bottom line, as stated by The Computer Sciences Corporation [5] is that companies that thoughtfully *choose their partners* and have a resolve to focus on one product at a time will accomplish successful collaboration. To accomplish this, companies must redefine their "rules of engagement" for product development – by ultimately transforming a competitive environment into a collaborative one, look beyond technology or existing systems and define collaborative processes (which include performance measures, participants as well as technology). In Figure 1-1, Bauer et al [6] show the use of technology and collaborative processes in industry capabilities. However, how is the choice of a collaborative partner made across industries?

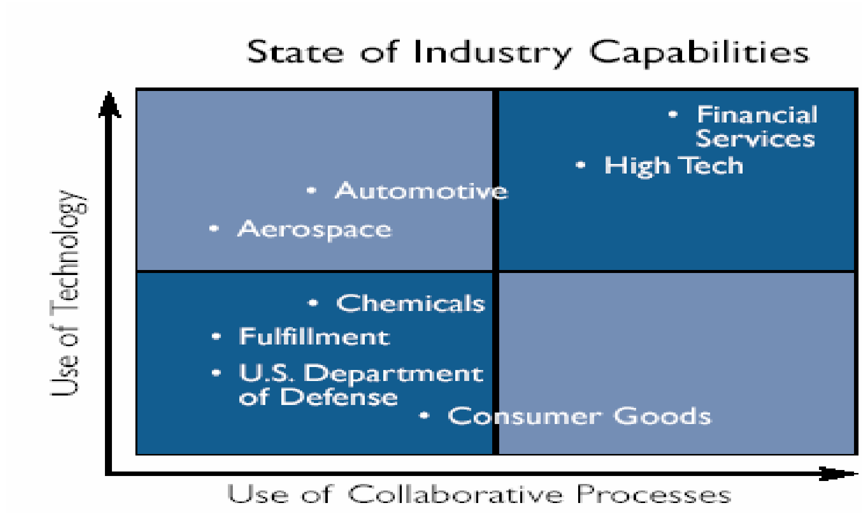


Figure 1-1 State of Industry Capabilities

True collaborative web-based environments are *secure, distributed, trustworthy, interoperable and flexible.* A distributed network is a system of two or more computers, terminals and communication devices linked by wires, cables or a telecommunications system in order to exchange information. Groups of such distributed networks are able to function separately and operate independently of similar networks. The network may be limited to a group of users in a Local Area Network (LAN), or be global in scope e.g. the Internet.

Why build distributed systems? According to Mullender [7], people are distributed and as a result, information is also distributed. Distributed systems often evolve because of a desire to communicate and share information and resources. Information generated in one place is often needed in another. Information and communication technologies have improved the way business is done and companies are becoming increasingly location independent. Computers have also evolved over time in order to keep up with the distributed environment.

With the advent of Very Large-Scale Integration (VLSI) technology, the processing power to cost ratio of computer microprocessors has increased considerably [8]. This has provided an incentive to develop microprocessor based *Distributed Computer Systems* (DCS) that have the advantage of increased reliability, modularity, survivability, responsiveness and incremental growth. Other reasons for distributed systems include, but are not limited to the following:

- Performance/Cost (Distributed systems are economic or profitable)
- Modularity (In contrast with centralized systems)
- Expandability **(**Capable of incremental growth)
- Availability (Data replication, built-in redundancy)

Product design is a vital part of the entire product development process. It involves the recognition and imposition of constraints, preferences, ergonomic issues, service requests/provision and economies of manufacture. Constraints in product design arise from business, technical, aesthetic issues etc. Adequate product design improves performance, resolves conflicts and reduces the overall cost of creating/manufacturing the product.

However, the difficulties in designing complex engineering products do not arise simply from their technical complexity [9]. The managerial complexity, necessary to manage the interactions and distribution of services between the different engineering and non-engineering disciplines, imposes additional challenges on the design process.

In recent years, Concurrent Engineering (CE) has become increasingly important for product development. The CE philosophy that suggests the need to consider design issues simultaneously in contrast to sequential considerations done in the past. The sequential design process (see Figure 1-2) has been considered inefficient, since this type of design process is very time consuming and inefficient when problems are encountered [10].

Unlike its traditional and problematic counterpart, the concurrent engineering design uses team approaches to bring departments together, including the input elements, processes and output elements necessary for production [11].

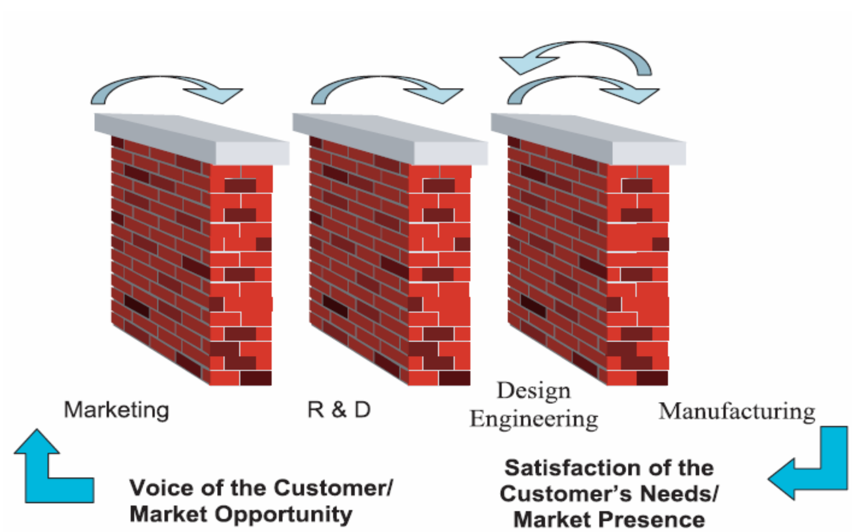


Figure 1-2 Traditional & Sequential Product Development

In product development, a wide variety of functional services and collaboration are needed. In this research, such services are classified as computational (involving direct computer-based interaction with design data e.g. a finite element analysis) or non-computational services (not involving direct computer based interaction with design data e.g. a part/component supply service). Services may also be resident, remote or a combination (hybrid) of both. Special focus in this research is on remote service trustworthiness and provision.

Joshi and Lauer emphasize the need for a well-developed design capability for first tier suppliers in product design [12]. A project begins at the concept stage and moves through design, to the development of production drawings of parts, tooling, etc. The objective is to provide a more efficient service and a faster response time in servicing customer needs.

For example, consider the development of a new product by an auto manufacturer. A product concept is completed at the Design Studio and is presented to the Body Engineering department, which begins to design the structure of the vehicle. Changes during the evolution of the vehicle (product) are negotiated between the designers and engineers who are charged with the detailed design of the various subsystems of the product. Designers are responsible for generating the drawings under its engineers' direction. Designers also communicate their information needs and provide feedback to engineers.

With successive prototype vehicle building cycles, other groups of service providers enter the picture and with their input the final production vehicle design develops through an iterative process of negotiated needs and functional requirements. Thus, collaboration is a vital process as depicted by Mesa International [13] in

Figure 1-3.

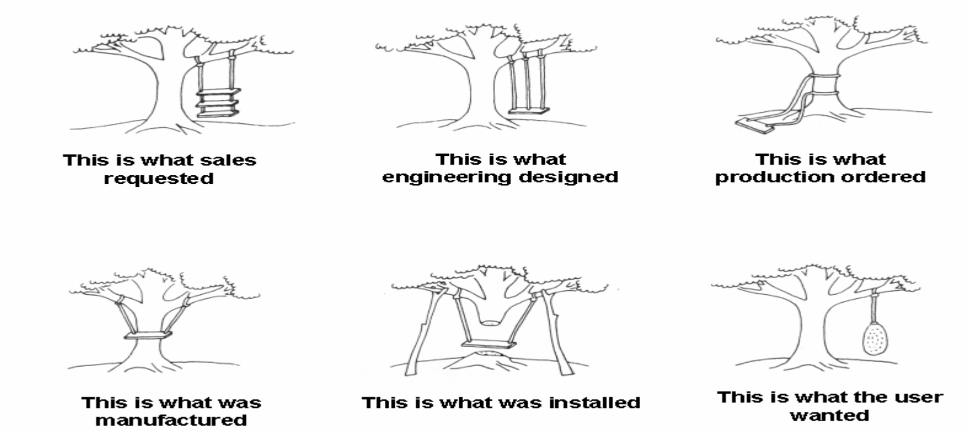


Figure 1-3 Do we need to collaborate?

1.2 TRUE COLLABORATION, TRUST & SECURITY

Reducing costs, increasing speed and leveraging the intelligence of partners involved during product design processes are important benefits of Internet-based product development systems. The options for cost-effective product re-design or improvement are at their peak during the early stages of the design process and designers can *collaborate* with suppliers, manufacturers etc. to acquire a better understanding of associated costs.

However, current collaboration scenarios are inadequate for sensitive (intellectual property) data environments and do not represent *true collaboration*, which is defined in this research as collaboration in an environment which maximizes the benefits of trust relationships and which is based on a secure information infrastructure. Many organizations are overwhelmed by the complications and costs of monitoring all of their external (and internal) connections & activities and various vulnerabilities. Technology, itself, is rarely the limiting factor [14]. Decades of *cost-focused procurement* have created an environment of distrust that hinders organizations or groups from working together.

Electronic business (business using the Internet; also referred to in the context of this research as *e-Business*) depends on trust between two parties. Various definitions of trust are given in Chapter 2.

Also, security and the privacy it enables is a key issue in e-Business. Previous security models involved using a myriad of technologies to keep “intruders” out. Resistance to change itself also leaves many companies squabbling internally.

Nevertheless, making the leap to *true* collaboration will be the key to survival for many companies today and in the near future. Figure 1-4 shows trends towards collaboration and Table 1-1 Traditional versus Web-Based Trust Systems depicts traditional trust systems and their corresponding web-based implementations.

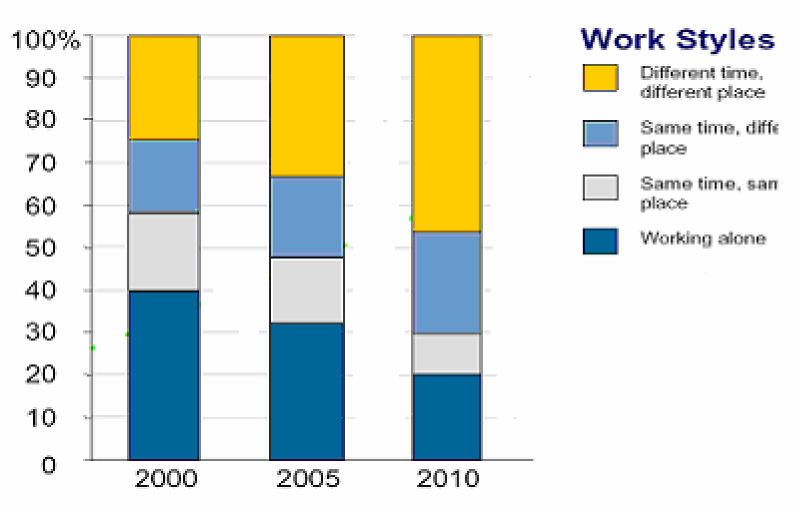


Figure 1-4 Trends towards collaboration

Table 1-1 Traditional versus Web-Based Trust Systems

Traditional	Web-Based
Paper-based Documents	Electronic Documents
Fingerprint	Biometrics
Handwritten Signature	Digital signature
Key	Password
Branding	Branding
Photo ID	Authentication
Authorization	Public Key Infrastructure
Business Card	Signature File
Qualification	Digital certificates
Physical Meetings	Videoconferencing

According to Webster's New World College Dictionary [16], security is the state or feeling of being or feeling secure. It is freedom from fear, anxiety, danger, doubt etc. From a technological point of view, security implies a condition of protection pertaining to information or infrastructure. It is protection or defense against attack or interference. Computer security is a vast field and distributed network security can range from physical threats such as theft and fire, to infrastructure security where authorization, authentication etc. come into play.

There are alternative formal definitions of computer security, but in this research, computer security is defined as *a means of preventing intruders, attackers or other unauthorized persons, from achieving illegal objectives through unauthorized use or unauthorized access of computers, peripherals and networks.*

Narrowing this definition, computer information security concentrates on the following three categories: Confidentiality, Integrity & Availability.

1.3 RESEARCH BACKGROUND: THE *PEGASUS* PROJECT

Customers have changed the way discrete product manufacturers operate. There is a gradual deviation from the traditional *make-to-stock* production model to a *build-to-demand* model. Many customers are no longer satisfied with mass-produced goods. They are demanding customization and rapid delivery of innovative products. The current method of designing a *mechanically engineered* product is for a designer with knowledge of design rules, product specifications and manufacturing preferences to evolve a design.

Today's Computer Aided Design (CAD) systems do not allow direct imposition of multi-disciplinary preferences regarding functionality, manufacturability, assembly, safety, reliability, ergonomics, material, and other issues against which such products should naturally be tested. While *view* and *edit* functions on a product can be accomplished at remote locations in some advanced CAD systems, there is no platform which allows a customer at a remote location to participate in the design of the product through the imposition of design preferences and acquisition of product development services. The e-Design Service-Oriented Architecture (known as the *Pegasus* Project) with a general overview is shown in Figure 1-5 The Pegasus Project. The goal of this project is to research and develop a scalable, flexible, and efficient collaborative *web-based* product design & realization platform. This platform will allow a customer and a manufacturer to work on a product concurrently.

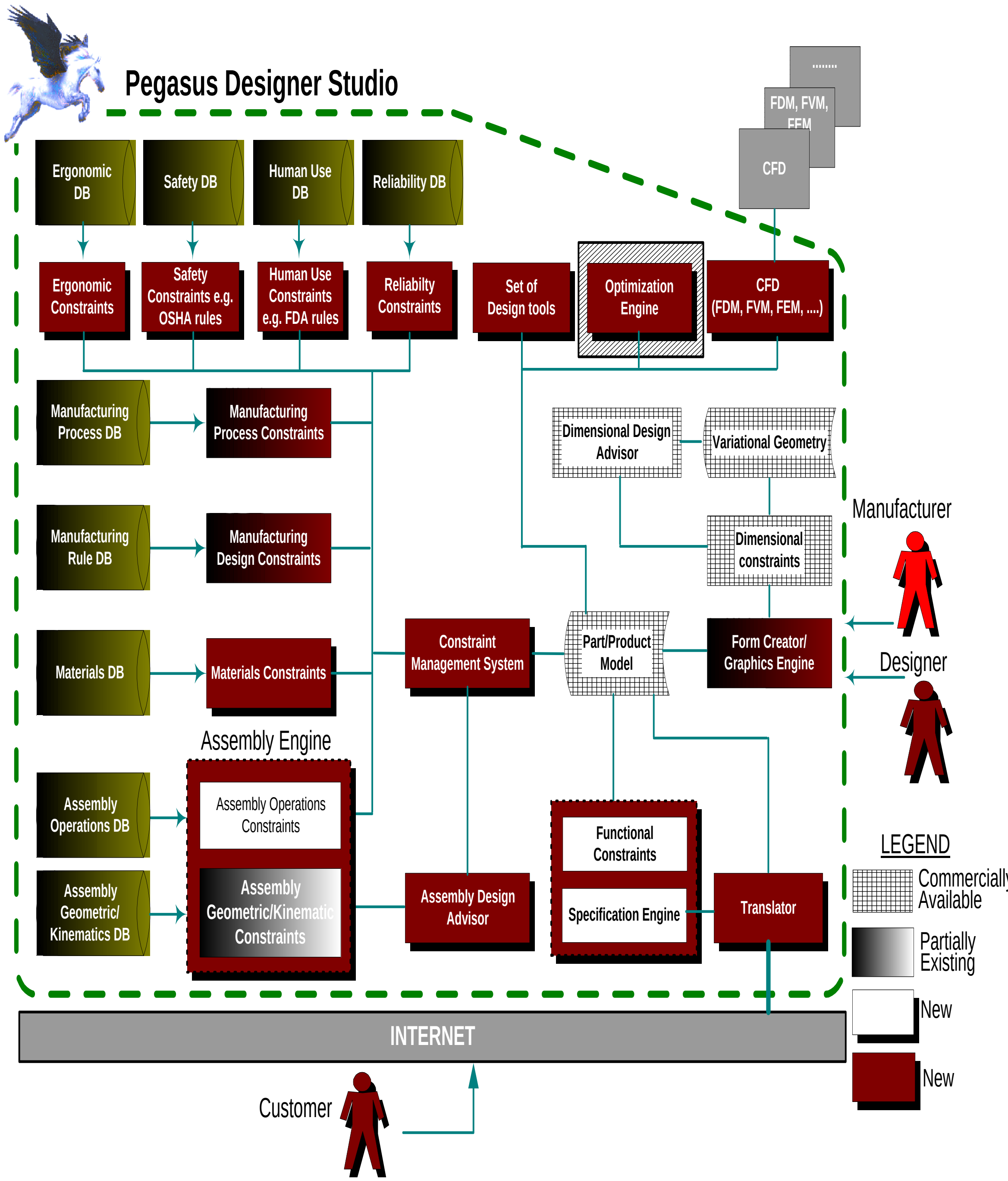


Figure 1-5 The Pegasus Project

1.4 STATEMENT OF THE PROBLEM

Collaboration is by no means a new paradigm. However, companies have found *distrust* of collaborative partners to be the most intractable obstacle to collaborative commerce, especially in intellectual property environments, which handle propriety data on a constant basis. An example of such an environment is the electronic (Internet-enabled) product development (*e-Design*) environment, where a product is conceptualized, designed, manufactured and realized using tools that allow for collaboration among multidisciplinary partners including service providers. Currently, there is a huge lack of trust on the Internet. The problem of distrust for services is also reinforced with collaborative e-Design environments that are distributed in nature or involve little or no prior and/or extensive contact.

In Internet-enabled product development environments, the dynamic assessment and/or reassessment of collaborative partner service provision are either inadequate or totally non-existent. In this research, *a service* is defined as a process (computational or non-computational), which provides a functional use for a person, application program or another service within the system e.g. Design, Analysis, Procurement (Supply) and Financial services. Service availability is published (or advertised) within the e-Design environment.

However, there is no formally defined or established standard or format for choosing a service provider (Figure 1-6) based on a *trust measure* related to *trust criteria tradeoffs* with respect to the service provider's recorded and computed performance. Also, some of the criteria that affect trust are somewhat subjective, may be conflicting and have no formal classification. Thus, there,

there is a need to formally investigate a *trust for service* building/creation, maintenance, assessment and realization framework in electronic product development environments.

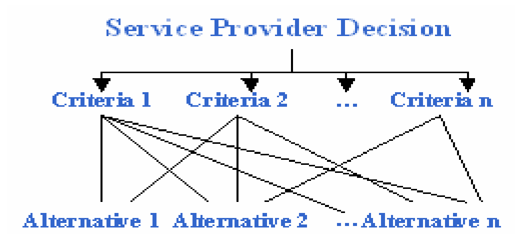


Figure 1-6 Choice of Service Provider

The primary benefit of the Internet is its ease in making information and a vast communication network economically available to virtually everyone. As a result of Internet benefits, the envisioned structure of the e-Design environment (known *as the Pegasus Project*) is made up of three main parts, which communicate via the Internet as shown in

Figure 1-7. These are the e-Design Center, the Client Modeler and the Service Provider.

The e-Design Center Server performs service brokerage functions such as service publication, service lookup and service planning or scheduling for services delivered by service providers. The client component of the design environment uses services to achieve the product conceptualization, design, manufacture and realization.

However, with a published directory of services, on what basis do clients select services? This question is especially relevant in assessing remote services.

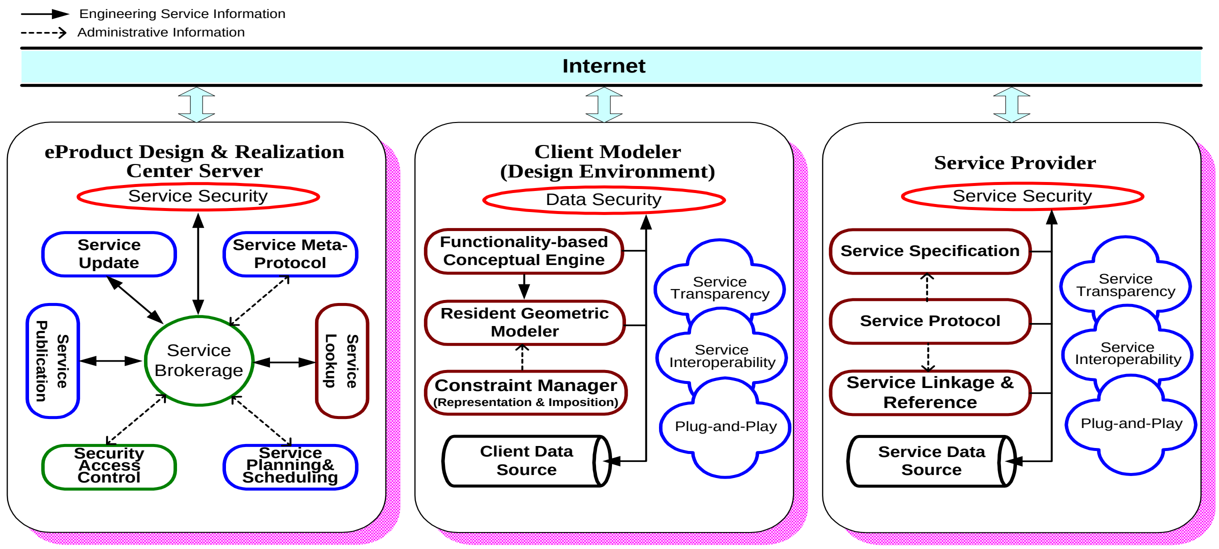


Figure 1-7 Structure of the e-Design Platform

How can efficient assessment and selection of services within the product development environment be enabled? Also, how can service users take on new services from service providers with whom they have never before interacted?

Today, on the Internet and in electronic commerce situations, service users may afford to take certain levels of risks when making a purchase of a book or some other item over the Internet using a credit card, for example. This transaction involves the transfer of personal and private financial information from the buyer of the item to the seller of the item. In some cases, the buyer of the item may not have previously interacted with seller. On another hand, even if the buyer had previously interacted with the seller, there is no guarantee that a new transaction may be totally without risks as well. Such risks may be somewhat affordable or diluted by other factors such as the ‘customer protection’ terms of the credit card company, or the maximum amount that can be lost through that transaction.

However, when dealing with product design and development environments (e-Design environments), transactions usually involve intellectual property and other sensitive data. Also, in the e-Design environment, the selection of a potential service provider has much larger consequences and thus, service provider assessment and selection decision-making is critical in enhanced or true collaboration to alleviate associated risks and mitigate information asymmetry. In this research, one major basis for such assessment and selection is termed *trust.*

Many users have low levels of trust in *e*-design and lack the tools to help them identify partners who are worthy of their trust. The current lack of trust is a threat to the growth and adoption of innovative and true collaborative product design. Figure 1-8 depicts some components of trust. Clients/users request design services from various vendors or service providers within the e-design framework, but there is no mechanism or framework to determine or evaluate trustworthiness of services provided during *e*-design transactions.

Thus, trust is very important to a firm's e-business strategy [17]. Various criteria such as network data, policy data and user feedback data, contribute to the assessment of service provider trustworthiness in collaborative product design. For example, service reliability increases trust. According to Parasuraman [18] and Van Gorder [19], reliability is fundamental to product or service quality. In a robust environment, the trust objective entails optimizing such factors or criteria.

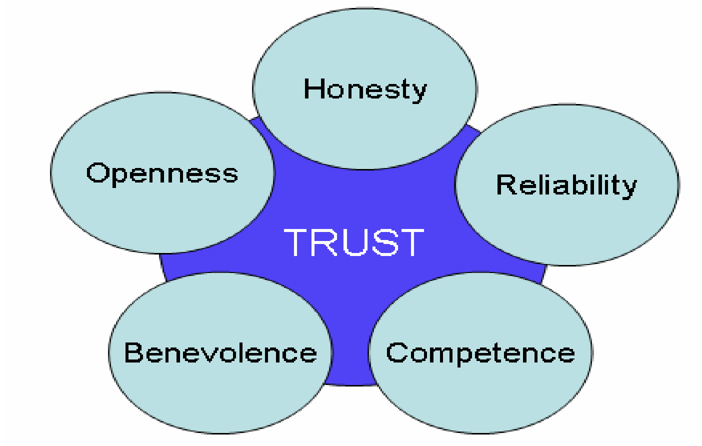


Figure 1-8 Some Components of Trust

Segal [20] also adequately restates the problem: "Without trust, people are suspicious of each other and refrain from sharing openly. For creative ideas to emerge, trust and openness must prevail". The Northwest Regional Educational Laboratory (NREL) [21] defines the component of trust as follows:

Benevolence: Having confidence that another party will protect your interests and this is a key ingredient of trust.

Reliability: Reliability refers to the extent to which you can depend upon another party to come through for you, to act consistently, and to follow through.

Competence: Similar to reliability, competence has to do with belief in another party's ability to perform the tasks required by his or her position. For example, if a principal means well but lacks necessary leadership skills, he or she is not likely to be trusted to do the job.

Honesty: A person's integrity, character, and authenticity are all dimensions of trust. The degree to which a person can be counted on to represent situations fairly makes a huge difference in whether or not he or she is trusted by others in the school community.

Openness: Judgments about openness have to do with how freely another party shares information with others. Guarded communication, for instance, provokes distrust because people wonder what is being withheld and why. Openness is crucial to the development of trust between supervisors and subordinates, particularly in times of increased vulnerability for staff.

The problem of trust on the Internet is complex and multifaceted. Users do not trust the system/infrastructure for transactions. Another issue is being able to determine the quality of information and transactions within the Internet. There is also lack of trust in the governance (policy definitions) of the Internet. Current trust research focuses only on security and metrics. However, there is a paradigm shift towards trust issues. A user-centered perspective to the problem of trust needs to be adopted. Trust is much more than security. Some people reduce the trust problem to one of security, arguing that, if security issues are resolved, people will be happy to transact online. However, when the trust problem is broken down into its constituents, trust for service is much more than security mechanisms that are currently in place to enable computational security as opposed to perfect security.

Thus, there is the need in enhanced collaborative product development to investigate and develop a trust for service infrastructure to efficiently convey an expression or measure of trust for services in e-Design. An appropriate trust for service framework will serve as a complementary tool in e-Design and development, enabling or improving the delivery of efficient service provision.

1.5 RESEARCH SIGNIFICANCE AND MOTIVATION

The significance of this research includes:

- Current dominance of Service-Oriented Architectures (SOA)
- Benefits of the accessibility of trustworthy distributed services
- Importance of the supply chain and other service providers in e-Design environments
- Absence of existing formalized trust building/maintenance processes and the need to improve current remote service selection methods
- Internet-enabled, collaborative and distributed product development may typically involve a lack of similarity, mutual organizational security and familiarity
- Trust is fundamental to human interaction and cooperation

Benefits of a trust for service infrastructure in e-Design include better productivity, quality performance, seamless service provision boundaries, unlimited geographical issues, increased competitiveness and price regulation among service providers.

In support, Wheelwrite [22] notes that product life cycles are shortening and businesses must compete globally using networks and other advanced means of communication. Networks have become indispensable for conducting businesses and transactions in industry, academic organizations and government. A networked system provides access to information and enhances collaboration at a fraction of the cost and the Internet provides an opportunity for connecting to seamless boundaries at record speed.

According to a survey by NerveWire [23], an American consulting and systems integration group, companies found distrust of business partners to have been the most intractable obstacle to collaborative commerce. Lack of trust is one of the greatest barriers inhibiting online trade between buyers and sellers who are unfamiliar with one another [24]. Therefore, understanding how online trust is created and maintained can lead to improved sales, revenues, profitability, and ultimately shareholder value. Trust also reduces uncertainty [25], is a form of organization control [26] and is a transaction cost reduction mechanism [27].

The propagation of trust becomes a major issue when several entities are involved in electronic commerce transactions. Trust makes cooperative endeavors happen and is a key to positive interpersonal relationships in various settings because it is central to how entities interact with others [28]. Hence, trust in e-Design is a non-trivial issue. Smith, in his report, lists trust, confidence, security and privacy as barriers to e-transactions [29].

The complexity of trust increases with the value of service. According to Kinsella [30], purchasing online is increasingly becoming common and accepted but trust and security are still fundamental for future growth. Throughout history, successful business relationships have been fundamentally based on trust, so naturally a comprehensive and trusted infrastructure is essential to the future success of the marketplace. However, Kinsella, as most other researchers, refers mainly to a *strictly e-commerce* environment, where individuals permit and acknowledge an acceptable level of risk in handing out credit card numbers over the Internet as payment for goods purchased. The penalty for this acceptable level of risk is not comparable to levels of risk associated with collaborative product design transactions and processes. The collaborative product design environment is very different, even though it certainly has the elements of e-commerce embedded within its processes as well.

Mutual suspicion among managers is also slowing the growth of collaborative e-business. According to Kehoe [31], trust – or rather, distrust – is the highest barrier to implementing advanced e-business applications, such as supply chain management and product design collaboration systems that link companies to their suppliers, customers and business partners. However, Kehoe makes an interesting statement – "… the heart of the issues is not a lack of faith in Information Technology systems but rather a lack of trust in the *people* with access to them". Nevertheless, despite the fact that this research recognizes the impact or influence of people with regards to trust, suitable trust-support infrastructures can still facilitate improving trust-relations in web-based product design. Such infrastructures would provide adequate flexibility for human input, which is more or less mandatory for any practical model, which involves some form of user input or feedback.

In a transparent service-oriented collaborative environment, there are a lot of players rendering various services. Such services include product conceptualization services, drafting services, design services, ergonomics services, simulation and rapid prototyping services, assembly services, finite element analysis services etc. Security services alone are insufficient in assessing service provider trustworthiness or in determining which service provider to enlist for collaboration. For example, consider digitally signed code versus "*competent*" programmers, where the problem actually lies in determining if the "*competent*" programmers are actually competent.

Another example is the issuing of certificates and the dubious owners who hide behind the certificates. An adequate trust for service framework will enrich the quality of information available to the user and mitigate information asymmetry regarding the trustworthiness of services on the network. Service providers must be trusted to a reasonable (practical) degree to provide the stated service in a dependable or reliable manner and such significance cannot be over emphasized.

1.6 RESEARCH FOCUS, OBJECTIVES AND CHALLENGES

This research focuses on building *trust for services* in Internet-enabled collaborative product design environments. *Trust* is defined, in the context of this research, as a quantifiable degree of belief or ranking based on specified "good qualities". It is the main driver or enabler of successful collaborative efforts or transactions in Internet-enabled product design environments. This research adopts the idea of *enhanced or true collaboration in Internet-enabled product design* based on a framework of trust for service provision.

The focus in this research is on investigating the problem of service provider trustworthiness determination and decision-making in the case of remote service provision. Concentration is on characteristics specific to *electronic* product design (e-Design) environments and remote service provision. This research is a subset of an NSF sponsored research project being conducted at the NSF Center for e-Design at the University of Pittsburgh. Design environments should be trustworthy, scalable, flexible and secure to ensure efficient collaboration. It should allow a customer and a manufacturer (and other partners) work on a product concept/design concurrently, and to provide the customer, in virtual space, the capability to specify preferences, which impose domain specification constraints on the product and the product's components.

Service requests and corresponding service delivery should be transparent and safe to the user. The environment should have efficient trust infrastructures, which will ensure that true/enhanced collaboration exists. The primary objectives of this research are as follows:

i) To investigate and analyze trust for service issues with respect to the impact of the Internet on corporate, distributed, enterprise-wide e-Business networks

ii) Identification of the critical trust issues concerning honestly, openness, reliability, competence and benevolence and investigate suitable means of data collection and the relationship of the collected data to trust through studies and statistical analysis

iii) Design and development of a suitable framework and trust-support infrastructure along with complementary frameworks for building vital trust architectures for services delivered in electronic- (web-based) product design and realization;

The challenges of this research include:

i) The deviation from the more familiar route of trust research (security issues or metrics alone) based on a foundation, which affirms that 'trust is more than security'

ii) Analyzing trust from a user-centered perspective and providing a methodology for incorporating trust with regards to service deployment in a real time, distributed environment

iii) Presenting the user with an estimate of trust or a quantifiable degree of belief based on a transparent and logical methodology and incorporating ease of use and pragmatic applicability to a varied set of potential users. Such a package should be worthy of "operational use" in current business environments.

1.7 APPROACH TO THE PROBLEM

In the absence of prior contact with a collaborative partner, collaborative participants need to rely on other factors such as the general reputation of the other collaborator, service quality, service availability, service consistency, commonalities of race, gender, age, religion, geographic location, or upbringing (depending on situations) etc., to assess how trustworthy they are. The more interaction the parties have over time, however, the more their willingness to trust one another is based upon the other party's actions and their perceptions of each other's intentions, competence, and integrity. This is the underlying approach to the trust for service problem investigated in this research.

In the physical world, we acquire trust based on some assessment of certain desirable qualities. The same applies in the electronic world where certain user-relevant criteria are assessed to form a degree of belief or measure called *trust*. Companies can improve online trust by enabling the disclosure of patterns of past performance, providing references from past and current users, getting third-party certifications, and making it easy to locate, read and enforce policies involving privacy and security [32].

Focusing on the assessment of service providers for e-Design collaboration, relevant criteria are classified into two groups – Network Data (defined as data that is automatically measured or recorded in the network such as service wait time, number of transactions or conflicts within a specified period etc.) and Non-Network Data (defined as data, which requires some prompting or input by the client and may be considered more subjective but not necessarily insignificant such as user feedback etc.). Studies will be conducted to evaluate network and non-network data. For Network Data, the desire is normally to minimize the measurements obtainable, hence, smaller is better e.g. least service response time. For Non-network data, the opposite is usually the case where the highest rating or reputation is desired.

Thus, the comprehensive problem regarding choice of service provider (a trust decision problem) is approached as an objective optimization problem (for Network Data and Non-network Data) in which the client desires to select a service provider who is the best alternative in relation to some ideal point and based on tradeoffs (compromises) on trust-related criteria, some of which may be conflicting. In an ideal world, this ideal point would represent some service provider with excellent scores on all criteria across the board, which in most pragmatic situations is more or less infeasible.

However, to introduce some degree of flexibility, the client may define his/her/its ideal point, by presenting threshold criteria within company specification and allowances. The integration of these ideas is the basis of the Design Environment Trust Service (DETS) Framework. This framework provides a structure for supporting and enclosing service provider selection during the e-Design process based on criteria, which is used to build a measure of the degree of trust. Preceding this methodology is the need to:

- Identify/review current trends and practices regarding the issue of trust for service provision in web-based collaborative product design; The process also involves a critical analysis of related fields and contributing factors
- Identify shortcomings in current trends and practices (if any practices exist)
- Identify key or characteristic elements of trust management/information security needs, requirements and possibilities

The overall research hypothesis is stated as follows:

Hypothesis: Trust for service provision can be built, incorporated and maintained within an electronic product design environment by providing a suitable framework to collect, analyze and report trust-related data based on specified parameters used in evaluating a potential group of service provider candidates.

1.8 RESEARCH ORGANIZATION

In this document, a literature review of related research issues is presented in Chapter 2. Chapter 3 introduces the Design Environment Trust Service (DETS) framework and presents relevant research background, definitions, the information architecture within the Design Environment and the Trust Service Infrastructure. Chapter 4 discusses the details of the methodology, while Chapter 5 discusses model validation and implementation. Chapter 6 concludes the document, summarizes the research and discusses possible research extensions. A list of bibliographical references is given in the Appendix. The Appendix also contains detailed survey design samples, data analysis and other results.

2.0 LITERATURE REVIEW

Mesa International [13] defines *Collaborative Manufacturing* as a strategy by which all appropriate individuals and organizations – both internally and externally – work together to better support business processes using real-time information, integrating design, planning, production and delivery. Such an environment is the basis for a new product design paradigm in which service-oriented collaboration is of optimal importance and significance. Various researchers describe trust and related trust management systems in a strictly e-commerce environment. However, this research analyzes trust from the point of view of product design service delivery and service quality/response measurements and assessment for service provider selection.

2.1 SERVICE PROVIDER SELECTION

Traditionally, service provider selection methods involve a lot of effort on the part of the service requester and this could imply significant diversion of useful man-hours. How important is selecting the right service provider? Finding the right service provider can make the difference between success and failure in product development projects. This significant detail is emphasized when considering product development products that involve huge amounts of intellectual property and money e.g. the manufacture of a car, a top-of-the-line airplane, a military armored vehicle etc. Below are some current and typical service provider selection steps or procedures:

- An internal business analysis
- Local service provision market research
- Potential service provider applications and interviews
- Possible visits to potential service provider sites, which may be locally or otherwise located
- Possible signing of service provision contracts, legal documents or the need to redo the entire process or some segments of the process in the event that no suitable potential service provider was identified

These steps can be time consuming, expensive, limiting and may not ultimately achieve the desired goal, which is choice of the right service provider or vendor. In a distributed global product development environment with seamless boundaries, there is the need for a better service provision selection and reassessment framework. There also the need to apply typical factors that influence service provider trustworthiness decisions. For example, choice of the right service provider can be gauged based on public reputation or recommendations and these are both valid approaches [33]. Publicly validated information can provide unbiased answers to critical questions that can help in the selection of a service provider and greatly increase consumer confidence.

Consumer confidence is recognized as the key barrier to the predicted growth in e-Business, which requires the trusted transmission of information on products, services and service provision [34].

The European Commissioner for Health and Consumer Protection, David Byrne [35] emphasized the fact that while Internet penetration is growing rapidly, all the evidence shows that consumer confidence in the e-Commerce medium itself and in cross-boarder transactions remains low and affected by the *'e-confidence barrier'*. The Commissioner points out that there are a series of consumer concerns including:

- *Privacy and confidentiality of data:* Consumers are wary of their information being misused;
- *Quality of service and delivery of products:* Surveys show that too many e-businesses still do not get the basics right and simply fail to provide what the customer paid for;
- *Full and fair disclosure:* For example, pricing. All too frequently, prices are misleading e.g. not including delivery cost plus any other hidden charges;
- *Handling of complaints and redresses:* Complaints need to be facilitated and addressed (e.g. a dispute resolution system vs. legal system) especially given the transactional nature of e-Commerce.

If these concerns are not resolved, e-Business will continue to suffer low productivity and stifled performance. Hence, there is a significant and present need to investigate solutions to these problems in order to ensure adequate service provision in e-Design.

Other important points on service provider selection include expectations as described by Dasgupta [36]: the service provider's vision, stand in the market, success, scalability, customer support plan, general reputation, flexibility, response to deadlines budget considerations, customer satisfaction, training, unnecessary bells and whistles, lack of competitiveness etc. Poorly managed infrastructures also breed lack of accountability of service providers and market domination. Many analysts also cite lack of accountability as a major stumbling block for wide scale adoption of e-marketplaces [37].

2.2 TRUST DEFINITIONS AND ITS IMPORTANCE

Researchers and practitioners have shown sufficient interest in *trust* that it has become a widely studied and highly heralded concept [38]. A wide variety of trust definitions, leading to a plethora of in-use meanings of the concept have been used. This has resulted in confusion regarding how to compare one trust research result to another.

Trust is central to teamwork, leadership and organizational culture [39] [40]. The academic research community agrees that trust is essential in all relationships [41] [42] [43] [44]. Trust is increasingly recognized as a social good or social capital that is fundamental to human interaction and cooperation [45] [46] [47] [48]. Hardin [43] also states that there is no agreed definition of trust.

Trust is one party's belief that another party will behave in a predictable manner and is sometimes described as a highly complex and multi-dimensional phenomenon. Williamson [49] describes trust as a term with many meanings. Mayer, Davis & Schoorman [50] focused on trust as a willingness to be vulnerable to another and their trust construct is based on two types of antecedents of trust: (i) a propensity to trust (similar to a personal disposition to trust), and (ii) a set of three perceptions regarding the other person's trustworthy attributes: *ability, benevolence and integrity*. They introduced a model, which includes risk as a moderator of the relationship between trust and risk taking. However, this model does not take into consideration specific aspects critical to the e-Design collaboration scenario and about two decades worth of changes regarding trust beliefs and issues. Figure 2-1 depicts relationships among trust constructs.

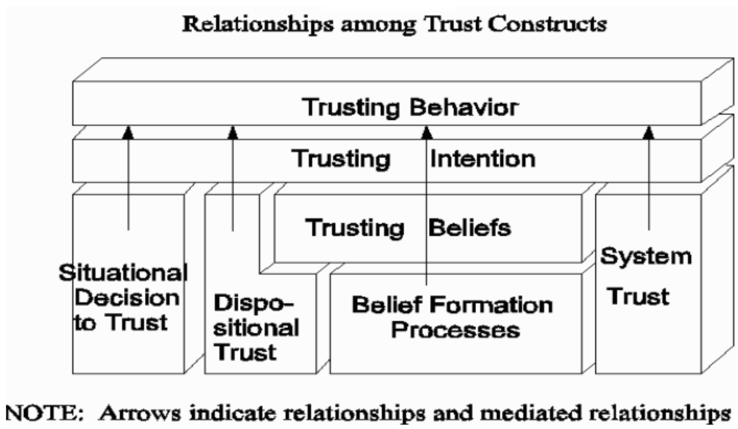


Figure 2-1 Relationships among trust constructs

Mishra [51] defines trust as a party's willingness to be vulnerable to another party based on the belief that the other party is competent, open, concerned, and reliable. Mishra argues that trust is an overall construct that is made up of the combination of four belief dimensions. That is, trust is a multi-dimensional construct formed by certain beliefs. Mishra also describes beliefs as combining in a multiplicative way: that is, a low level of trust in terms of any of the dimensions offsets high levels of trust in terms of other dimensions.

Hwang and Burgers [52] define trust as the probability one attaches to cooperative behavior by other parties, while McKnight et al. [53] state that trust is an individual's beliefs about the extent to which a target is likely to behave in a way that is benevolent, competent, honest and predictable in a situation. Doney [54] discusses credibility and benevolence as the underlying dimensions of trust. Credibility refers to the buyer's belief in the seller's expertise to do the job effectively, while benevolence is based on the buyer's belief in the positive intention of the seller [55].

Trust is important wherever entities interact especially in electronic communities [56]. Managing Trust is a problem of particular importance in peer-to-peer environments where one frequently encounters unknown entities [57]. Guha et al [58] state that a trust model is a fundamental building block in many of today’s most successful e-commerce and recommendation systems. Other researchers also describe trust as a judgment of unquestionable utility as humans use it every day. However, trust has suffered from an imperfect understanding, a plethora of definitions and informal use in the literature and in everyday use. It is common to say, “I trust you”. However – what does it really mean? [59]. In e-Design, it is very important to develop a formalism to adequately determine and interpret a measure of trust for service provider selection.

2.3 OTHER TRUST RESEARCH & THE NEED FOR A NEW TRUST MODEL

This research approaches trust from a different perspective than the usual associations of trust research that are described shortly. In this research, trust is analyzed with the requirements of multi criteria service provider selection and is viewed as a *multidimensional* construct. There are few existing and emerging trust infrastructures and the widespread use of the Internet signals the need for a better understanding of trust as a basis for secure and confident on-line interaction. In the face of increasing uncertainty and risk, users must be allowed to reason effectively about the trustworthiness of on-line entities.

Current trust research focuses solely on issues like Public Key Infrastructures (PKI), security, trust metrics, risk formulation, reputation management etc. Public Key Infrastructures (PKIs) can provide corporations and end-users with authentication. This is facilitated by the provision of digital signatures, registration and validation systems to enforce relevant security policies. PKI uses cryptographic key pairs (one public and one private) to uniquely identify devices and individuals exchanging electronic information.

However, security alone cannot guarantee the trustworthiness of service providers in an e-Design environment. In support, Abdul-Rahman and Hailes [60] outlined the shortcomings of current security approaches for managing trust and proposed a model for trust based only distributed recommendations. Again, this is a useful approach but neglects certain parameters such as network-validated data for remote services and other factors, which would also aid in providing a better estimate of trust.

A multitude of factors may contribute to trust for service provision and these factors can vary depending on the circumstances. A client/consumer may be willing to trade a fraction of the service response time for improved service quality. Also, risk assessment alone may not define the whole picture of service trustworthiness. Service provider history and certain event history analysis data may also be of influence to the decision-maker. Hence, there is the need for a wholesome and extendable trust for service infrastructure in which criteria may be flexibly appended or eliminated, depending on the decision-makers choice.

New trust models must enable the decision-maker delegate trust responsibly and effectively understand how the measure of trust is computed. There should also be transparency and upward-compatibility with existing infrastructures. A wholesome trust model should be able to keep up with research extensions and new trust frontiers. In the e-Design trust service research, focus is on providing an acceptable estimation of trust for service provider selection and not just verifying electronic transactions. Information must be acquired from data in such a way as to simulate human cognitive processes like reasoning, intuition and perception.

Atif [61] states that while security protocols such as the Secure Sockets Layer and Secure Electronic Transactions will ensure that a credit card number will not be intercepted during transmission or exchange, they provide no guarantee against its misuse by the receiving party or against fraud by the transmitting party. Atif also states the need for not only new protocols but also new transaction processes and proposed a distributed search algorithm and network of trusted intermediaries that can establish a trusted channel through which terminal transacting parties deal virtually directly and risk free with each other. While this approach definitely appears appealing, there is the question of ‘trusted intermediaries’ and how this status is achieved.

Khare [62] refers to an infrastructure for automated trust management applications in an open system like the World Wide Web and discusses the need to provide private network connections and reliable naming services for locating Internet devices below the HyperText Transfer Protocol. Standard trust management tools are needed on top of web clients and servers to help automate everyday trust decisions using signed assertions. However, a lack of flexibility and the absence of adequate decision support systems have made emerging trust models inadequate [63]. Also, users express nervousness in relinquishing absolute control at once and there is the desire to establish trust routines, increase delegation and reduce continual monitoring of systems.

Blaze [64] examined existing authorization mechanisms and their inadequacies. He describes some existing trust-management engines, including *PolicyMaker* and *KeyNote*, which are described as being either too general or too specific. Another key point on emerging trust systems is the lack of a product design perspective on web-based trust issues. Most research looks at trust purely from a financial/monetary point of view.

Product design has specific issues, which should be investigated separately. There is the need to adequately distinguish between e-commerce and e-design, despite the fact that these two areas do share some common boundaries. Even, in e-commerce, Atif [61] still stresses the inadequacy of current trust schemes and emphasizes the need for new protocols and new processes for trust.

Also, Yahalom et al [65] discuss trust in distributed environments and emphasize that fact that a formal tool to analyze trust requirements in security protocols is required. They also mention that there is no *effective and formal* way to reason about trust in distributed systems and defined trust classes, proposing a formalism for analyzing trust in authentication protocols. However, the e-Design Trust framework adopts the idea of a social control, utilizing objective elements within the network and using subjective elements within the same network to qualify the objective elements. The goal is to optimize a trust objective, using dynamic values and creating a flexible but usable trust infrastructure.

2.4 TRUST CONCEPT PARADIGM SHIFT

Companies' perception of online trust is steadily evolving from being a construct involving only security and privacy issues on the Internet to a multidimensional, complex construct that includes reliability/credibility, emotional comfort and quality for multiple stakeholders such as employees, suppliers, distributors and regulators, in addition to customers [66]. However, creating and maintaining trust in a global virtual team whose members transcend time, space, and culture is challenging and any trust that results may be fragile and temporal [67].

Thus, trust may exist in the mind of the consumer, waxing and waning with ongoing experience and, to a great extent, out of the direct control of the company. Trust can also be a matter of perception built through security technology, policies, publicity etc. So, security is necessary but *insufficient alone* for propagating trust within a network. Nevertheless, security demands that all devices in a pervasive system must be able to authenticate each other and communicate in a secure manner and this is usually achieved through trusted third parties (Trusted Authorities) like a Pubic Key Infrastructures or Key Distribution Centers [68]. However, Abdul-Rahman and

Hailes [60] point out that Trusted Authorities can never be a good enough authority (or "recommender" of trust) for everyone in a large distributed system. The credibility of the Trusted Authority depletes and its recommendations increase in uncertainty, as its community of trustees grows.

2.5 TRUST CRITERIA DETERMINATION

There are numerous criteria that can contribute to trust and other researchers have readily investigated and identified some of these criteria. Hoffman et al. [69] focus on security and privacy as the key drivers of online trust. Smith et al. [70] include longevity and an online community as potential drivers of trust. Perceived reputations also determine trust in an electronic environment [71]. Previous experiments have also been conducted to determine criteria that affect online trust.

For example, an empirical study regarding users perception of web-site credibility was conducted on 1400 students in the US and Europe, evaluating over fifty different web-site elements relating to trust [72]. It was discovered that ease of use, expertise, and tailoring affected web credibility and trustworthiness.

Yoon [73] also studied trust in the context of online purchase decision-making through simulation and surveys and concluded that web-site trust is determined by company awareness, reputation and consumer familiarity with e-commerce. Prior satisfaction ratings also had significant contributions to trust in e-Commerce. The process of building trust is gradual and feasible with the proper framework. However, loss of trust can be rapid and difficult to rebuild.

In the e-Design trust research, such trust criteria or factors are classed into two main groups – (i) the network data (also known as objective data, which is any criteria or factor that can be measured and validated automatically without prompting such as service wait time etc.) and (ii) the non–network data (also known as subjective data, which are criteria that cannot be measured automatically and requires prompting or input from the client or system such as previous user feedback on service ease of use etc.).

For service wait time and most network data, small is better e.g. smaller service response time. However, for user feedback, a higher (or "big") rating is desired. Thus, there are multiple objectives or criteria to optimize.

2.6 MULTI CRITERIA DECISION MAKING

The need for multi criteria decision-making (MCDM) arises in countless tasks addressed by modern technology, as well as in everyday human activities [74]. Multiple criteria evaluation provides a process for combining data according to their importance in decision analysis. The most recently researched or used technologies for multicriteria evaluation and decision support include the Analytic Hierarchy Process developed and primarily documented by Thomas Saaty (AHP) [75] [76], Multicriteria Rank Ordering (MRO) [77], the Worth Trade-Off Method [78] and Probabilistic Multidimensional Scaling [79].

AHP is a powerful and flexible decision making process that helps in determining priorities and making the best decision when both qualitative and quantitative aspects of a decision need to be considered. It reduces complex decisions to a series of one-on-one comparisons and then synthesizes the results. Decisions can be structured into smaller parts, proceeding from the goal to objectives to sub-objectives down to the alternative courses of action. Decision makers then make simple pairwise comparison judgments throughout the hierarchy to arrive at overall priorities for the alternatives.

AHP's strength lies in its ability to structure a complex, multiattribute or multicriteria problem hierarchically. Pairwise comparisons of elements (attributes or factors) are established using a 1–9 scale that indicates the strength in which one element dominates another. The scaling process is then translated into priority scores (or a normalized set of weights) for the comparison of alternatives. AHP applications include multi criteria decision-making and resource allocation.

In Multicriteria Rank Ordering, decision-makers simply rank the order of the complete set of alternatives from best to worst. In all MCDM cases, the aim of the method is to optimize the given set of objectives or criteria according to some specification. Other types of optimization models have also been formulated and these include: linear program formulations, non-linear formulations, goal programming formulations and compromise programming formulations.

Goal programming is a management science technique that is commonly used to analyze multiple objectives in a decision-making environment. Compromise Programming was proposed by Zeleny [80]. In compromise programming, a "deviation" variable is introduced to represent the distance (deviation) between the aspiration level (ideal point) and the actual attainment (feasible region).

Figure 2-2 depicts the compromise programming concept.

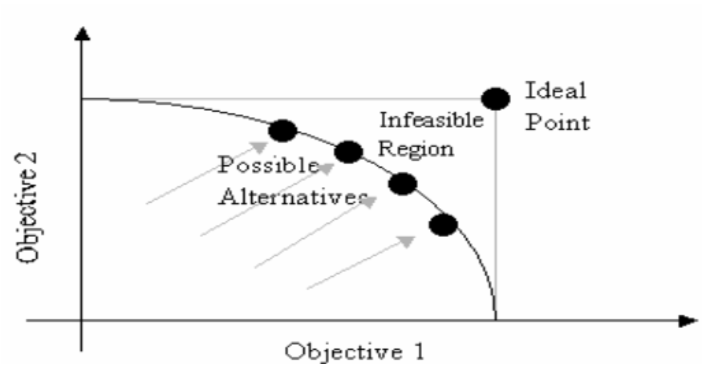


Figure 2-2 Compromise Programming

When the decision-maker designates more than one criterion, it is possible that the criteria are non-commensurate and in conflict with one another. In the mathematical sense, there is no unique optimum solution and therefore a compromise solution with respect to the several objectives should be sought [81].

Compromise Programming involves utilizing the multiple criteria available within the network and performing tradeoff analysis to select the best alternative from a set of possible solutions. By seeking a solution as close as possible to the ideal point, compromise programming requires less information on the decision maker preferences than goal programming and fewer computations than multi objective programming [82].

Also, unlike other methods, the decision-maker does not need to have available a utility function to quantify the benefit of a given alternative. The alternative that minimizes the distance to the ideal point is the optimal solution to the decision problem. Steuer [83] mathematically proved that Compromise Programming is superior to the weighted-sum method in locating efficient solutions. However, the decision maker may still apply weights (to the objectives) in compromise programming.

2.7 NETWORK & NON-NETWORK DATA

Successful businesses depend on accurate information. Such information is valuable, and can be bought, sold, traded and stolen. Information can determine the future lifespan of a company. For example, the stock market is a multi-billion dollar industry. Investors who have the most useful information are the ones who have a better chance of maximizing their profits. In the same vein, network and non-network data are used in this research to fortify a knowledgebase of trust data. However, the issue is how to establish a quality cache of information. According to Davenport and Prusak [84], qualities that make information valuable include:

- Accuracy - inspires confidence,
- Timeliness - appropriately current
- Accessibility - can be readily located when required
- Engagement - capable of making an impact and/or influencing a decision

- Application - relevant and useful within the defined context
- Rarity - possibly provides a hitherto unknown or confidential insight

Actions that turn vast quantities of data and information overload into value-added information that can be absorbed, applied and acted upon include:

- Pruning: eliminate the obsolete, the irrelevant and the inaccurate
- Adding context: through summary, analysis, comparison, synthesis, and conclusion
- Enhancing style: through effective variation and interactivity, creative staging and inspirational dramatization
- Choosing the right medium for presentation: take advantage of the range of media available for delivery of your message - Internet / intranet access, video displays and teleconferencing overhead or slide-based presentations phone calls or face-to-face communications hard-copy reports, e-mail or faxes regular mail or courier.

Value is added to data in order to create meaningful information by customizing it, categorizing it, performing calculations, making corrections, and condensing it. Cramer [85] examines issues and methods of measuring the value of information. Topics discussed include the difference between information and data, the contextual reference for value, the different value standards for types of information, an organizational information model, and methods of attributing value. However, these methods have various limitations. Also, the abstract nature of these concepts makes it difficult to see a clear way to measure the value of information, even though there are established ways to quantify and characterize associated data.

Often a small amount of information will have greater value than large amounts, thus there is no direct relationship between the quantity of data and the value of the associated information. For this reason, it would be a mistake to use purely communication metrics to analyze information operations. The need to design cost-effective information protection architectures adds new urgency to this classic problem. There is no single metric that applies in all circumstances, but an approach using multiple metrics can be useful.

3.0 RESEARCH FRAMEWORK AND FOUNDATIONS

This chapter presents relevant information and research foundation. It includes research definitions, terminologies, the underlying e-Design and trust for service infrastructure and background to the data studies.

3.1 RESEARCH DEFINITIONS

Research definitions include the following:

- *Trust:* In this research, trust is studied in the context of *trust for service* and defined as: A quantifiable (or ranked) belief based on client-specified (or default) "good qualities". Focus is on the cognitive description of trust as shown in Figure 3-1 Trust: Cognitive and Emotional.

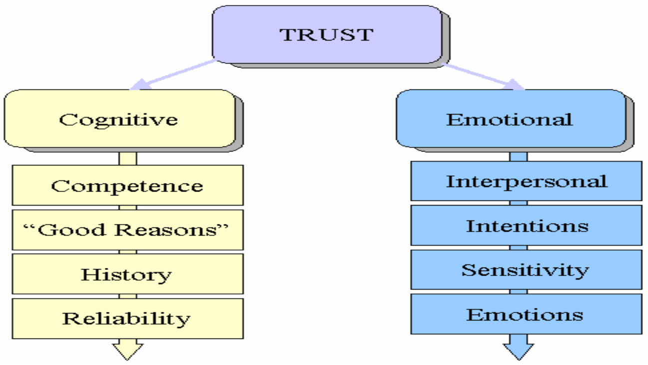


Figure 3-1 Trust: Cognitive and Emotional

Trust for service expressed by Party A regarding Party B for a specified service S is a quantifiable degree of belief in Party A that Party B behaves or will behave in a manner specified, standard or agreed upon regarding the service for a specified period.

- *Service:* Design is an interdisciplinary and multifaceted process that requires contributions from various participants. These contributions are broadly termed *services.* In this research context, a *service* is defined as a process, which provides a functional use for a person, application program, or another service within the system.

The research is based upon a service-oriented concurrent engineering platform whose goal is to provide customers, designers, suppliers, manufacturers and other stakeholders the opportunity to participate in the design, development and realization of a product.

Services can involve other services [86] [87]. Examples include single-customer multi-vendor transactions. Various design and analysis tools serve as *service providers* for different services needed in the collaborative design process. Collaborative e-Design services include, but are not limited to assembly services, drafting services, ergonomics services, financial services, analysis services etc. Figure 3-2 depicts more services associated with the e-Design infrastructure;

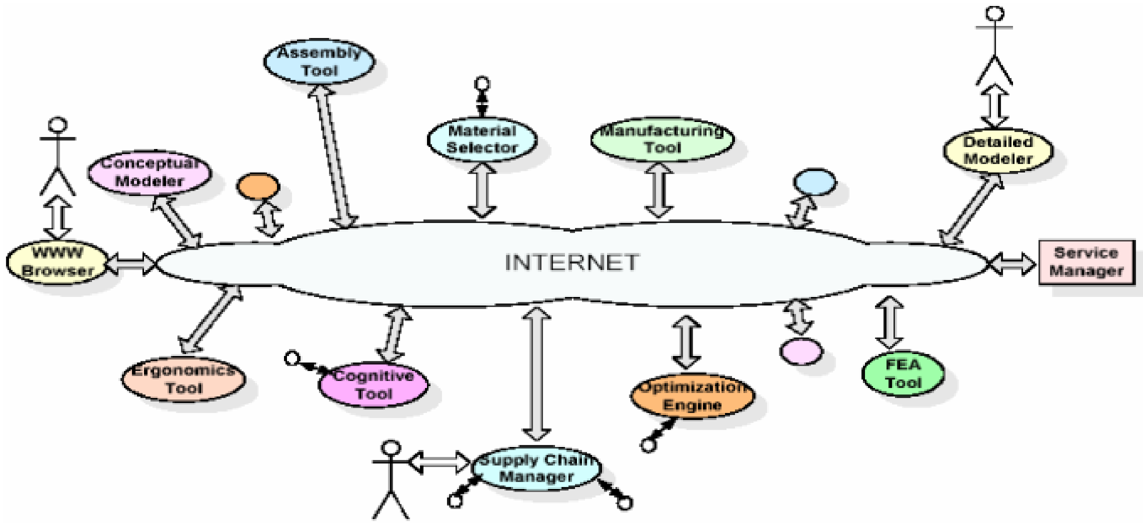


Figure 3-2 e-Design Infrastructure Services

Services are classified as *Computational or Non-Computational Services.* An example of a computational service is an analysis service such as Finite Element Analysis (FEA), a computer-based numerical technique for calculating the strength and behavior of engineering structures. It calculates deflection, stress, vibration, buckling behavior and many other phenomena using computers as a result of the astronomical number of calculations needed to analyze a large structure. With Finite Element Analysis, the weight of a design can be minimized, and there can be a reduction in the number of prototypes built.

An example of a Non-Computational service is the supply service from a supplier, which has no or little significant computational effort. Services may also be resident with the client's system, may be invoked/requested from a remote source or may be a hybrid service (both resident and remote).

- *Entities:* These are the users, partners, clients, customers, service providers or objects in the *e*-Design network. An Entity X, can take on various forms depending on the role being played at that particular time.

For example, an entity may be a customer at a given time, but may also take on the role of a supplier to another customer (client) at another time. It may also change from to a system integrator, a designer, a manufacturer, a service provider etc., depending on the specific role being played at the specified time.

Complex schemas may include single entities maintaining multiple roles simultaneously in different e-Design environments across different cultural or time boundaries. Figure 3-3 depicts Entity X with some of the forms it may assume.

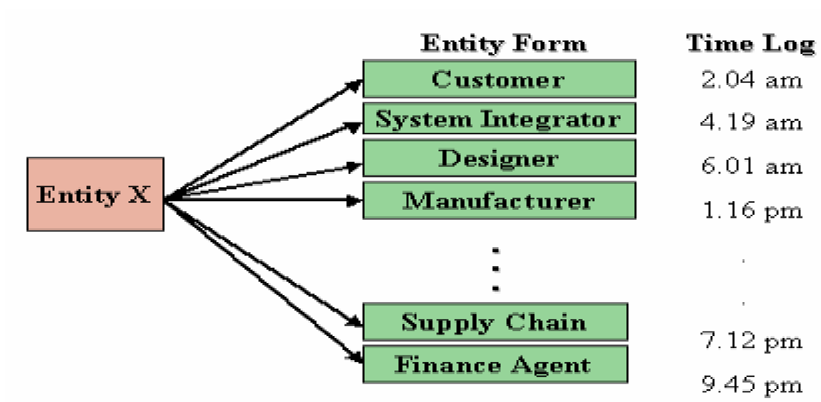


Figure 3-3 Entity X

- *Client:* The client is the entity that uses a service selected from a directory containing published services within the e-Design framework. The Client Modeler, existing at the client-side of the network, is one of the three main components within the envisaged e-Design infrastructure

- *Service Provider:* The Service Provider provides the service to the client. Such services are published and broadcast to the Service Manager located at the e-Design Center platform

- *The e-Design Center:* This is the common point of control. The Center furnishes clients with services published by service providers. The Center also regulates services from service providers and accepts trust evaluation requests from clients. It is a Joint National Science Foundation/Industry University Cooperative Research Center (NSF/IUCRC) for e-Design and Realization of Engineered Products and Systems.

  Currently, the universities involved in this research include The University of Pittsburgh, The University of Massachusetts, The University of Central Florida, Carnegie Mellon University and Virginia Polytechnic Institute and State University. The Platform upon which the design environment operates is known as *Pegasus.* Application areas include aerospace and automotive industries as well as selective application in medical devices

- *e-Design:* e-Design is the process of conceptualizing, designing and realizing a product, using tools that allow for interoperability (of remote and heterogeneous systems), collaboration (among multi disciplinary partners including service providers who may supply a computational or non-computational service to a client) and virtual testing and validation of a product within a secure Internet-based infrastructure. e-Design allows for lean data exchange and active customer participation through direct preference imposition

- *User Feedback and Reviews:* This is information prompted from a client or entity within the e-Design environment. Reviews are similar to feedback and are used to periodically gather information about the service of an entity e.g. a service provider. EBay.com [88] and Amazon.com [89] were used as case studies in studying user feedback/review scenarios and the effect such data have on the overall system. Figure 3-4 depicts the EBay user feedback system while Figure 3-5 shows Amazon's Review system.

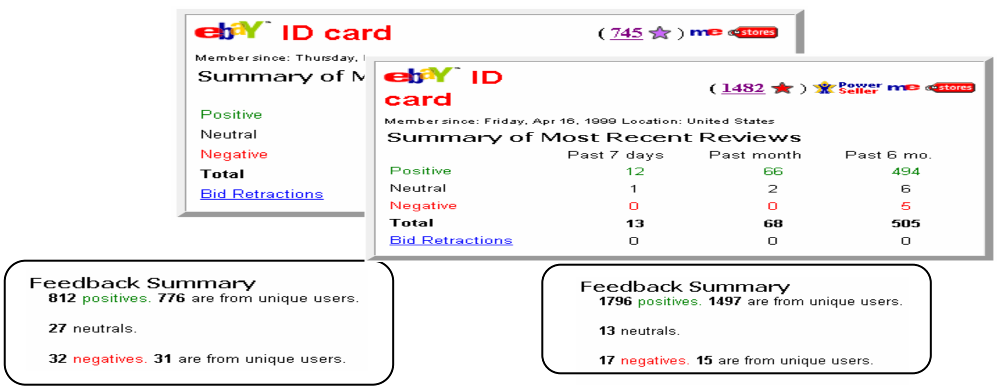


Figure 3-4 Ebay's Feedback System

Figure 3-5 Amazon's Review System

- *Events:* An event is a qualitative change that occurs at a specific time within the network or system

- *Crisp and Fuzzy Sets:* A crisp set is also called a classical set and assigns a membership of either 0 or 1 to objects within their universe of discourse. On the other hand, a fuzzy set assigns grades of membership between 0 and 1 to objects within its universe of discourse. Hence for Z, a universal set holding elements {*Y*}, the fuzzy set V is defined by its membership function:

$$\mu_V: Y \rightarrow [0, 1]$$

which assigns to every *Y* a degree of membership μ_V in the interval [0, 1]. Support for a fuzzy set, also known as the degree of fuzziness or fuzzy spread is the set of points in *Y* for which μ_v is positive and is stated mathematically as:

$$Supp(A) = \{y \in Y | \mu_v(y) > 0)$$

3.2 THE E-DESIGN SERVICE ARCHITECTURE

The multidisciplinary and multifaceted nature of engineering design and product development introduces the need for diverse services within the collaborative product design, development and realization platform. However, collaboration also entails issues like uncommon communication protocols, diverse operating systems and different programming languages. The proposed design environment will provide engineering services and make such services available for transparent product development processes. The foundation for such transparency is the explicit definition of engineering service protocols within the system. Services are also specified from the functional aspect of service providers. Figure 3-6 shows the service relationships within the e-Design system. Existing or new services from service providers are registered with the Service Manager through a process known as *Service Publication*. The Service Manager module is shown in Figure 3-7.

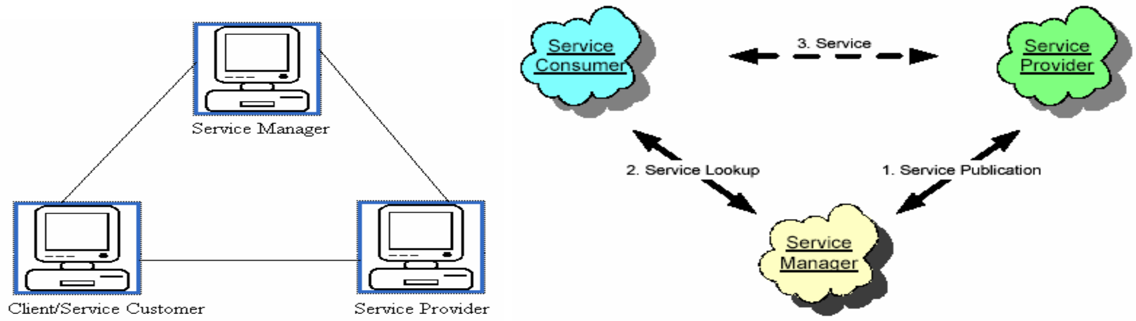


Figure 3-6 Triangular Service Relationships

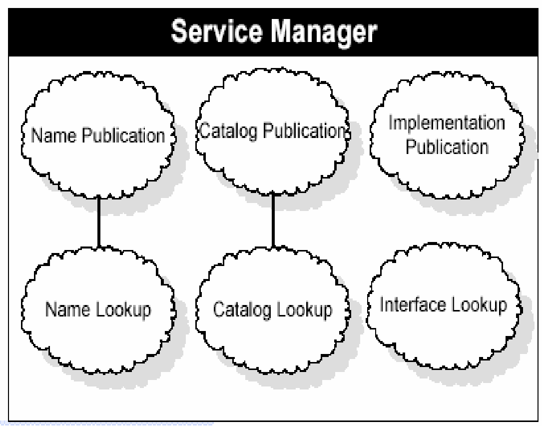


Figure 3-7 Service Manager

3.3 THE *E*-DESIGN TRUST INFRASTRUCTURE & PROTOCOL DEFINITION

Product Development (for a new product or a re-design) involves the distribution and management of information throughout the production process. Most design processes include the need to maintain '*product-change-data*' throughout development and production. Other types of information in the e-product design network include procurement and supply chain information, business process information, financial information, engineering tracking and ordering, manufacturing information, engineering CAD design information, end user information etc.

The e-Design network requires a systematic and holistic way of satisfying information/data requirements. The e-Design information architecture is used to satisfy these requirements and it describes the various components of the overall information infrastructure. Major components include the data architecture, the systems architecture and the computer architecture.

The function of the data architecture is to ensure effective and efficient delivery of information, especially in the integration of disparate systems. Such integration provides real competitive advantage and improvements in efficiency. The data architecture establishes the "ground rules" for decisions about how data will serve the information needs of the organization by considering how the valuable data resources will be captured, merged, stored, maintained, transferred and finally used and exploited.

The Information and e-Design Trust Infrastructure will be defined for building trust in Internet-enabled collaborative product design. This infrastructure serves as a basis for and provides a structured way for describing the functionality of the various components of the trust for service model. The infrastructure also serves as building blocks, which define the framework for a comprehensive trust for service determination solution.

The trust for service framework developed in this research is called the Design Environment Trust Service (DETS) framework and its protocol is defined in three domains: the Service Manager Domain, the Client Domain and the Service Provider Domain.

Service Manager Domain:

- Registration of Clients, Service Providers
- Knowledgebase maintenance, validation and replication
- Event monitoring and notification
- Request For Trust Evaluation
- Computation of the Dynamic Trust Index or the trust measure rank
- Submission of trust data results to Client

Client Domain:

- Selection of Trust Evaluation Criteria
- Request for Trust Evaluation
- Selection of Service Provider

Service Provider Domain

- Selection of Trust Evaluation Criteria
- Request for Trust Evaluation
- Provision of service to client

3.4 DATA STUDY BACKGROUND

Various criteria and data require investigation in the Design Environment Trust Service framework. This includes two categories of data: non-network (user supplied or subjective) data and network (network supplied or objective) data.

A *User Feedback Study* was designed and developed using the popular online marketplace – Ebay.com and Amazon.com as preliminary case studies. According to the Ebay services declaration page [90], Ebay is committed to making trading experiences safe, enjoyable and easy; It has a multi-role setup and users are ensured of being able to make informed decisions with confidence and trust; eBay management also state that "a keystone of safe trading is knowing the track record of the person you are dealing with". Their sole mechanism for doing this is the Ebay feedback system and this has proved successful and effective, ranking eBay as one of the Forbes Fortune 400 companies [91].

However, it is noteworthy to emphasize certain differences as well as similarities between the Ebay platform and the e-Design platform. These are specified in Table 3-1 below.

Table 3-1 EBay & e-Design Comparisons

ebay: Online Marketplace	*e*-Design Platform
An **online platform** for **the sale of goods and services** by **a diverse community** of individuals and businesses	An **Internet-enabled platform** for the conception, design and development mechanically engineered products **involving diverse collaborators** and **the sale of services**
eBay **enables trade on a local, national and international basis** with customized sites in markets around the world	The *e*-Design environment **transcends seamless boundaries** enabling product design and development collaboration
Through an **array of services** eBay is enabling global e-commerce for an ever-growing online community	A **service-oriented collaborative product development environment**
In 2002, eBay members transacted **$14.87 billion** in annualized gross merchandise sales	The *e*-Design platform transactions involve **substantial financial transactions and implications** e.g. design costs, manufacturing costs, loss of proprietary information, loss of intellectual property
In eBay**, participants in the environment can take on multiple roles**; For example, a buyer in one transaction can be a seller in another transaction	In the e-Design environment, **a participant may be a client in one transaction and a service provider in another transaction**
eBay is dedicated to its community of members, and has **numerous services which enhance the trading experience**	**Tools which enhance the product development** are also necessary in the e-Design environment

Non-network data is presented as a natural language (linguistic) scale e.g. Service quality is "ok". This may also be represent as a number of a scale of say 0 (worst case) to 10 (best case). If a linguistically represented value of "5" is supplied by a service user and this is associated with the "ok" value, what does a value of 5.6 represent? Hence, the need apply a concept known as fuzzy logic, which was conceived by Lotfi Zadeh [92], a professor at the University of California at Berkley. Fuzzy logic is a way of processing data by allowing partial set membership rather than crisp set membership or non-membership. It is inherently robust since it does not require precise inputs. Also, fuzzy arithmetic is computationally simple and robust to moderate changes and does not require the assumption of correlation among inputs, unlike Monte Carlo methods that present a computational burden and a need to assume correlation among all inputs.

Network data is also utilized in the DETS framework. In large enterprise and service provider networks, high network availability is a mission-critical requirement in order to maintain global competitiveness and market advantage. The Internet as a network supports business applications and service provision and these processes are usually performed in real time. User/business productivity can be adversely affected if real time service provision is poor. Poor service provision can also lead to frustration, low confidence, deterioration in attitudes and a lack of trust. Thus, sufficient feedback on service provider *network-based* performance is an important element in the trust for service model.

The network performance should be sufficient to support the user or product design application's response time expectations. There is also the need for constant service availability, connectivity and high responsiveness to ensure e-Business competitiveness and viability.

The need for trust in service provision is especially critical in remote service provision where services travel across media like the Internet. Remote service provision can be affected by faulty DSL modems or cables, Denial of Service attacks, power failures, blocked ports, database failure, poor service tools, incompetent service providers etc. There are various existing network data collection tools, which companies use to collect, monitor and analyze network data. An example is AlertSite's Service Level Monitoring tool [93], which maintains data on agreed upon service levels, service availability and uptime, etc. Such tools also reduce costly down time by receiving instant notifications of errors or performance problems that would go undetected by internal monitoring tools.

4.0 METHODOLOGY

4.1 THE DESIGN ENVIRONMENT TRUST SERVICE (DETS) FRAMEWORK

One of the main objectives of this research is to investigate how e-Design clients can make decisions regarding service provider selection based on the concept of *trust for service*. Other research has been done regarding decision support in other applications such as geographic information systems [94]. The main idea in creating a pragmatic solution to the problem of service provision selection in the collaborative product development application area is incorporating a trust for service framework into the entire e-Design system. Such a framework should be logical, flexible and a good representation of practical client decision making in service provider selection processes.

Typical research pertaining to trust has focused solely on security [95]. Others focus only on recommendations or risk [96]. However, this research goes beyond security, even though security is a critical part of a trustworthy service infrastructure. Physical trust is based not only on relationships forged, certain evidence seen or recommendations made. Nevertheless, reputation-reporting systems are one of the most promising approaches for producing trust in online communities [97] and some implementation schemes have been researched [98] [99] [100]. Historical network data can also play an important role in the trust infrastructure. How can trust for an *e*-Design service be acquired and established electronically (beyond security mechanisms)? A typical scenario is a product designer in need of special analysis on a design part for certain tolerance information, or a manufacturer desiring to investigate certain material properties from current and standard material databases.

Such services may not be resident on the client machines. Thus, within what infrastructure can remote e-Design services be published and advertised? Also, under what framework can remote service providers be trusted to deliver expected service performance? In what way can current service provider selection methods be improved? Currently, the concept of trust in computing systems often seems either too simplistic or overly complex [101]. Noting that trust is such a fragile and elastic concept, how can a transparent, flexible, dynamic and trustworthy e-Design service provision infrastructure be guaranteed?

The e-Design paradigm aims at creating a platform where such services are transparently available and the Design Environment Trust Service (DETS) framework discussed in this chapter enables the building or creation of trust for service assessment in collaborative Internet-enabled environments. The DETS framework comprises of the formally defined DETS protocol, data from the e-Design network & e-Design service users and the Dynamic Trust Index (DTI) computation engine, which is the process by which the measure of trust for e-Design service provider selection is ranked or determined.

In an electronic product design environment, trust for a particular service depends on certain factors. Table 4-1, Table 4-2 and Table 4-3 depict examples of potential service provider assessment and trust factors for computational services, non-computational services and factors common to both groups, respectively:

Table 4-1 Service Provider Trust & Assessment Factors: Computational Services

Computational Trust & Assessment Factors E.g. Analysis Service
Service Wait Time
Service Processing Time

Table 4-2 Service Provider Trust & Assessment Factors: Non-Computational Services

Non-Computational Trust & Assessment Factors E.g. Manufacturing Service
Lead Time
Part Failure Rate

Table 4-3 Service Provider Trust & Assessment Factors: Common to Both

Trust & Assessment factors common to both groups	
Policy/Legal Data	# Conflicts/Time
Authentication, Integrity	# Contract Renewals/Time
Area of Specialty	Support (Client Inclination)
Price (Quote)	Length of time in Network
User Feedback (Reputation)	Geographic Origin
Technical Ability/Competence	Incentives (Bonuses etc)
# Transactions	Red Flag Events
Service Protocols	Customer Service (Help)

Trust and assessment factors may be classified into two broad groups: Network Data (e.g. Service Wait Time) and Non-Network Data. (e.g. User Feedback). Network data is data that can be validated over the network, e.g. by Clients, the Service Managers, Service Providers or software for distributed networks. This data is also called objective data. On the other hand non-network data, also called subjective data, is data that results from e-Design client opinions e.g. User feedback. Factors such as technical capability are somewhat difficult to measure and thus this research investigates the ability to capture such information using procedures such as subjective user feedback.

To perform a methodical investigation into the subject of trust for services and prove or disprove certain hypothesis in distributed collaborative environments, surveys and data experiment studies were conducted in order to collect and analyze data. The data study results aided in the development the trust framework and Figure 4-1 depicts the data transformation stages.

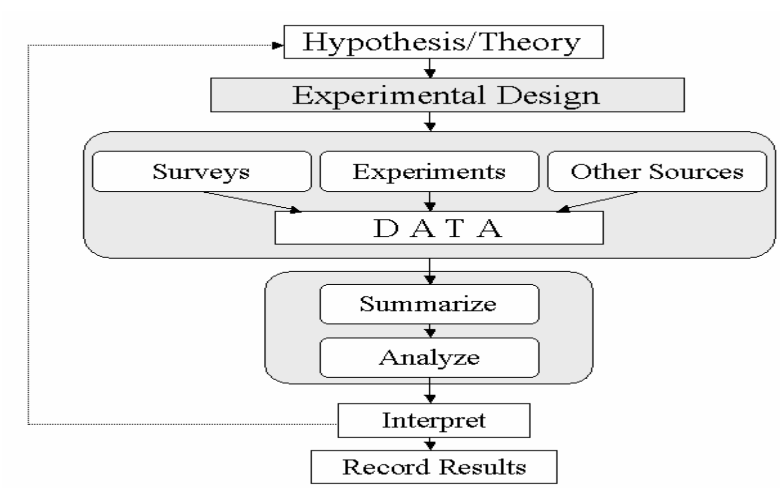


Figure 4-1 Data Transformation

4.2 RESEARCH HYPOTHESES, STUDY SETUP & DATA COLLECTION

The experimentation phase of the research verifies the validity of the data elements and the data evaluation that makes up the general DETS framework. There is no single correct approach to all evaluation problems [102], and thus a variety of analysis methods were used to investigate the data.

There are two main segments within this phase, namely: the *Non-Network Trust Data Study* and the *Network Trust Data Study*. The aim of these experiments is to determine (for the *Non-Network Trust Study*), the extent to which quantities such as service competence may be related with trust, built into user feedback & measured and (*for the Network Study*), the validation of measurable quantities over the network. Thus two hypotheses are defined. For the non-network data study:

Hypothesis 1: *Certain elements (trust factors or trust criteria) affect the perceived trust relationship between a client and a service provider (or between collaborative partners) in an e-Design environment*

For the network data study:

Hypothesis 2: *Certain data can be obtained objectively and directly from the network*

The studies were carefully designed to ensure the collection of the right data, which enabled the testing, and extension of the initial theories. The experimental design defines how the experiments were conducted with the following important issues considered:

- The type of experiment to be used
- The sample and/or population to be studied
- The optimum size (number of respondents) in the sample
- The optimum size of questionnaire
- The factors to be controlled in the experiment
- The variables to be measured during the experiment and the scales of measurement
- The type of analysis to be carried out on the collected data

4.3 NON-NETWORK DATA STUDY

Open-ended surveys, focus groups and interviews were used to gather preliminary data on the user feedback survey form design. These served as *pilot surveys*, which helped fine- tune the process for the main survey. The survey phases include:

- *Defining the objective of the survey:* Determining what factors contributes to a measure of trust for service provider selection and assessment is the primary objective of the survey. Also, how these factors relate to each other and to the dependent variable of trust is also important;
- *Defining the target population:* The target is a random sample of users who can provide a varied insight to trust for service relationships;
- *Defining the data to be collected:* The data typically involves trust criteria identification, relationships and interaction (particularly those that may be causal). Interesting patterns

in data are analyzed to determine relevancy for inclusion as factors in assessing service provider trustworthiness;

- *Defining the required precision and accuracy:* The most subjective stage is defining the precision with which the data should be collected. The precision provided by the sample survey is an estimate the 'tightness' of the range of estimates of the population characteristics provided by various samples;
- *Defining the measurement instrument:* The measurement instrument is the method by which the survey data is generated. In this research questionnaires, interviews, focus groups and observations were used;
- *Defining the sample frame, sample size and sampling method:* The *sample frame* is the group of people that make up the target population. In this case, these were people who have used an online service and could determine what would make such a service trustworthy. The *sampling method* was chose by convenience and availability of funds. A sample size of 100 or more respondents was initially considered with the target population being mainly industry personnel. This group was targeted because of the relationship between the e-Design service provision decision framework and an industrial setting

However, as a result of research constraints, the group of respondents included industry personnel, educational faculty members and students. The basis for calculating the size of samples is that there is a minimum sample size required for a given population to provide estimates with an acceptable level of precision. Any sample larger than this minimum size (if chosen properly) should yield results no less precise, but not necessarily more precise, than the minimum sample. This means that, although we may choose to use a larger sample for other reasons, there is no *statistical* basis for thinking that it will provide better results.

On the other hand, samples sizes less than the minimum may produce results with a lower level of precision. Again, there may be other external factors that make it necessary to use a sample *below* this minimum. If the sample is too small the estimate will be too imprecise, but if the sample is too large, there will be more work but no necessary increase in precision.

The estimates produced by a set of samples from the same population are assumed to be *normally distributed*. (This is *not* the same as saying that the values of the variable measured are actually normally distributed within the population.)

A well-designed random sample is the sampling method that will most usually produce such a distribution.

4.4 NON-NETWORK DATA COLLECTION

Various methods were used to collect information regarding non-network data. These include:

i) Focus Groups:

Two focus groups were used to collect data. The first consisted of 8 members of the National Science Foundation Center for e-Design at the University of Pittsburgh. This group of people participated in the preliminary data study and helped to determine core factors that contribute to an assessment of trust in distributed environments. The second group consisted of faculty from the Industrial Engineering department at the University of Pittsburgh and this group helped to refine the data collection process and procedures.

ii) Surveys/Questionnaires:

Surveys/questionnaires were also used to collect data and provide a lot of advantages such as a variety of questions and anonymous answers. By using surveys or questionnaires, respondents are given enough time to respond to the questions. Also, information can be collected on the same questions from all respondents. However, the surveys/questionnaires required some time to develop in order to ensure good questions.

Four major survey sessions were conducted. The first was an electronic questionnaire using the Internet as a distribution medium and it served as one of the preliminary sources of data for the formal surveys. The second survey session was a paper survey handed out to random respondents including faculty and survey experts from the University of Pittsburgh. The third survey session signified the first formal data collection and was conducted within the Pittsburgh area of Pennsylvania (mainly from the University of Pittsburgh main campus). The fourth survey session signified the second formal data collection and was conducted in Houston, Texas (mainly from attendees at the Institute of Industrial Engineers 2004 Conference). Over a hundred closed survey responses were collected. However, 97 (58 + 39) of these were complete enough to be used in the data analysis.

Respondents were randomly selected and each is assumed to be independent of the others based on personal and subjective conceptions of trust. Another reason for the independence assumption is that it is unlikely that the respondents all participate in totally identical service scenarios or respond in totally identical ways to service situations.

As a result of the independent random factors that act in an additive manner to create variability among the collected data, the data analysis assumes that the population follows a Gaussian (also called the Normal distribution) distribution as mentioned previously, so that inferences can be made about the mean and other properties of the population.

Even if the actual population is not Gaussian, the Central Limit Theorem (CLT) states that for sufficiently large samples (size at least equal to 30), the distributions of the means will follow a Normal (Gaussian) distribution even if the population is not Gaussian. Resampling was also an option considered during the data analysis in order to create a population of sorts by repeatedly sampling values from the original sample.

iii) Interviews:

Interviews were conducted with executives of Ford Motor Company. These interviews were structured dialogs in which respondents answered questions posed by the interviewer. Interviews were also conducted with other members of the NSF Center for e-Design at the University of Pittsburgh. Interviews allowed for the interviewer to pursue unanticipated lines of enquiry and acquire in-depth information on sensitive subjects.

iv) Previous Records & Observations:

Previous records were also a good source of data. For example, it has been previously researched and stated that extensions of trust include interface design [103] and communication [104]. Examples of other research studies are given in the Appendix. When properly investigated, previous records can complement data sources. However, previous records may also contain incomplete data. Observations help in confirming or raising questions regarding collected data. Such questions typically provoke a deeper investigation. Similar systems can be examined and analogies made as appropriate. Also, it is important to note that some of the data obtained from records and observations may not adequately apply to the distributed collaborative product development environment.

4.5 QUALITY OF NON-NETWORK DATA

To ensure the quality of data, there was the need to ensure *reliability* and *validity* of data. Reliability aids in measuring the consistency of the media for data collection. This is a non-trivial, time consuming and sometimes difficult process. Data reliability testing, for example

Test-retest reliability, was used to ensure the quality of the survey data collected. *Test-retest* reliability is based on the principle that the survey should produce the same or highly similar results if the same responder completes the survey twice.

Thus, four survey responders were randomly selected to retake the surveys. These respondents were conveniently selected so that they could easily be contacted at a later time (at least one hour apart) to retake the survey.

Validity of the data means that the data collection media actually measured what it was intended to measure. This is essential to ascertain that there are no other possible explanations for the data analysis results. Data validity was also built into the entire survey development phase by ensuring that appropriate questions were asked and such questions were not misleading. To achieve this purpose, a trial run or preliminary survey run was conducted at the beginning of the data study process. The data collection instrument was also analyzed by two data collection experts from the IE faculty at the University of Pittsburgh. This also emphasized the validity of the measuring instrument.

The cultural appropriateness of the questions is also important and also provides another way to deal with the quality of the data. Cultural appropriateness of the data collection medium ensures that respondents are not offended by the questions or by the way they are worded. Explaining the need for the data (as simply and briefly as possible) also goes along way in engaging the respondents. Contact information for survey results (e.g. an email address) also gets more people involved in genuinely providing sincere answers to questions. This is applied mainly to the questionnaires and interviews.

The non-network data is analyzed and potential network components are also investigated. These results are discussed in the next chapter. The analysis of the trust criteria resulting from the data study is used in the Design Environment Trust for Service framework for service provider trustworthiness analysis.

4.6 DISTANCE METRICS

In the Design Environment Trust for Service framework, a trust index is computed based on distances for a specified or default ideal (or target) point. Trust criteria are determined and compromises or trade-offs are performed on the data based on the decision-makers choices. The target or ideal point is the point that provides the best scenario for service provision. However, this point may also exist within a infeasible region.

Thus, the goal of the multi criteria decision-making system is to locate the point closest to this ideal point that lies within a feasible region. Factors that can induce infeasibility regarding ideal points include conflicting or complex trust criteria. Further discussions and demonstrations of the methodology are presented in the next chapter.

5.0 ANALYSIS AND MODEL RESULTS

Non-network and network were used in the model and analyzed as discussed below. Network data consists of objective data, which can be validated by the network. Non-network data includes user-feedback or historical information that may be more subjective in nature.

5.1 NON-NETWORK DATA ANALYSIS

The goal of the non-network data analysis is to make the strongest possible conclusion based on data randomly sampled from an infinitely large population. There are a variety of procedures from simple correlations between items to more elaborate statistical techniques that allow researchers to evaluate how items relate to other items, individually or jointly. Regression analysis and more complex statistical modeling procedures are based on the inter-correlations among items and can be used to identify clusters of items that fall together into single dimensions and to relate these items or dimensions to desired outcomes.

Generally it was found that user feedback, even though subjective, could be used as a source of contributory information to mitigate information asymmetry in service provider selection when properly implemented.

After the data collection phase, the data is compiled or recorded, coded, checked and analyzed. For the surveys/questionnaires, coding of the data was automatically represented in the design of the data collection medium. Hence, it was easy to readily transfer the collected data to the spreadsheet. The design of the surveys also provided quality control in the data entry process. This is because at certain portions of the spreadsheet, only certain values can be used. Hence, a quick scroll down the data entry page would reveal any data inconsistencies that have occurred.

Another way in which quality control was implemented was to perform the data entry process in phases and ask another party to randomly check at part of the data entries. If the checked entries provided some inconsistencies, the entire data for that entry phase was examined. Various categories of data were analyzed as summarized below:

Focus Groups, Interview, Preliminary Survey and Observations Data Analysis:

Insights and interpretations that occurred during these qualitative data collection phases are very important. Descriptive text is recorded and analyzed for similarities, patterns or important concepts and themes.

The data is also summarized as necessary and used for evaluation purposes. Qualitative data analysis provided the following main results:

- Refining and confirmation of the initial problem definition and significance
- Choice of 7 Main Trust Factors:

F1: *Presence of an Adequate Policy*

F2: *Service Ease of Use*

F3: *Service Conflict Resolution*

F4: *Service Response to Deadlines*

F5: *Previous User's Inclination to use Service Again*

F6: *Service Quality*

F7: *Overall Service Evaluation*

- Ensuring the validity and reliability of the other data collection instruments (e.g. the formal survey)

These results are the perceived responses of the respondents and the non-network trust criteria are investigated later in this documentation in order to determine any measurable quantities that can be extracted from them. However, previous literature has discussed using other methods such as Taguchi Loss Functions to evaluate individual criteria like quality & performance [105] [106] [107] and Quality of Service (QoS) studies [108]. The loss function philosophy indicates that the cost quality should be measured as a function of deviation from some target value [109] and this philosophy is related to the extended methodology applied in this research.

Survey/Questionnaire Data Analysis:

Surveys and questionnaires are more quantitative in nature. The data collected from the survey was analyzed in various stages using statistical procedures such as *descriptive statistics* (in which the data is described or summarized), tests for significant differences (in which changes and differences are examined between groups and subgroups).

Descriptive statistics described the characteristics of the data and made comparisons of characteristics between groups of data. In order to enable generalizations about a population, inferential statistics is used to analyze the "independent variable" (which in this case is trust) and the "dependent variables" (which are the trust factors). Hence, trust depends on multiple criteria.

Analytical Hierarchical Process (AHP):

The Analytical Hierarchical Process (AHP) is a data comparison methodology. Even though some critics still raise eyebrows about this methodology in some circles, it is still highly popular and widely accepted. The Analytical Hierarchical Process (AHP) was used to determine the default (system) weights for the trust criteria with respect to trust. Forming a pairwise comparison matrix A, where the number in the *ith* row and *jth* column gives the relative importance of F_i as compared with F_j using a 1-9 scale:

F_{ij} = 1 if the two factors are equal in importance

F_{ij} = 3 if F_i is weakly more important than F_j

F_{ij} = 5 if F_i is strongly more important than F_j

F_{ij} = 7 if F_i is very strongly more important than F_j

F_{ij} = 9 if F_i is absolutely more important than F_j

Thus, the average values from the collected data results in matrix .

	F1	F2	F3	F4	F5	F6	F7
Adequate Service Policy	1	6.2	5.5	5.63	6.26	4.1	4.11
Service Ease of Use	1/6.2	1	4.5	4.4	4.2	3.7	4.1
Service Conflict Resolution	1/5.5	1/4.5	1	4.4	4.85	4.2	4.2
Service Response to Deadlines	1/5.63	1/4.4	1/4.4	1	4.5	4.19	4.2
Previous User's Inclination to Use Service Again	1/6.26	1/4.2	1/4.85	1/4.5	1	4.5	4.4
Service Quality	1/4.1	1/3.7	1/4.2	1/4.19	1/4.5	1	3.8
Overall Service Evaluation	1/4.11	1/4.1	1/4.2	1/4.2	1/4.4	1/3.8	1

Below, matrix *A* is represented entirely in decimal notation:

A =

F1	F2	F3	F4	F5	F6	F7
1 .000	6.200	5.500	5.630	6.260	4.100	4.110
0.161	1 .000	4.500	4.400	4.200	3.700	4.100
0.182	0.222	1.000	4.400	4.850	4.200	4.200
0.178	0.227	0.227	1.000	4.500	4.190	4.200
0.160	0.238	0.206	0.222	1.000	4.500	4.400
0.244	0.270	0.238	0.239	0.222	1.000	3.800
0.234	0.244	0.238	0.238	0.227	0.263	1.000

To normalize the weights, the sum of each column is computed and divided by the column of the corresponding sum.

$$\overline{A} = \begin{bmatrix} F1 & F2 & F3 & F4 & F5 & F6 & F7 \\ 0.461 & 0.738 & 0.462 & 0.349 & 0.294 & 0.187 & 0.185 \\ 0.074 & 0.119 & 0.378 & 0.273 & 0.198 & 0.169 & 0.184 \\ 0.084 & 0.026 & 0.084 & 0.273 & 0.228 & 0.191 & 0.189 \\ 0.082 & 0.027 & 0.019 & 0.062 & 0.212 & 0.191 & 0.189 \\ 0.074 & 0.028 & 0.017 & 0.014 & 0.047 & 0.205 & 0.198 \\ 0.113 & 0.032 & 0.020 & 0.015 & 0.010 & 0.046 & 0.171 \\ 0.112 & 0.029 & 0.020 & 0.015 & 0.011 & 0.012 & 0.045 \end{bmatrix}$$

As can be seen in the normalized matrix, some of the numbers in the first row are much larger than the rest of the numbers and this indicates some inconsistency in the original comparisons. A consistency measure can be computed by using eigenvalues of the normalized comparison matrix. In order to determine the weights (scores), the average value of each row is computed and this results in the transposed matrix *W*. By construction, the weights should sum up to 1. The following results state that the weights of the non-network trust criteria decrease from F1 (Adequate Service Policy) to F7 (Overall Service Evaluation) based on perceived user responses and according to pairwise comparisons.

$$W = \begin{bmatrix} 0.382 & 0.199 & 0.154 & 0.112 & 0.083 & 0.058 & 0.035 \end{bmatrix}^T$$

Using *Expert Choice AHP software,* as shown by the snapshot in Figure 5-1, the relative importance of the criteria has a similar relative range.

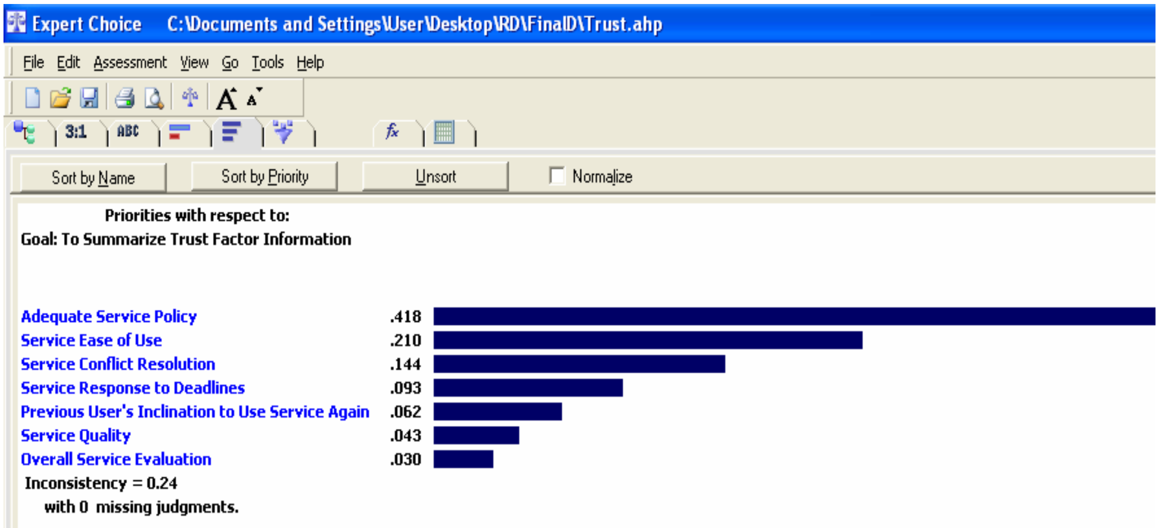


Figure 5-1 Analytical Hierarchy Process Snapshot

Thus, the data analysis using AHP determine that adequate service policies should carry the most weight in the model's default system settings. Overall service evaluation carries the least weight and these results in turn validate the reliability of the data collection procedure based on the logical argument that the overall service evaluation should practically be based on the outcome of the other factors. However, it is surprising that the service quality criterion does not carry a higher weight in the default system settings.

Univariate Analysis:

The analysis is accompanied by estimates of the margin of error or of the confidence interval that gives some indication that is useful for gauging how accurate the descriptions are. In analyzing respondent views to the relationship of the trust criteria to trust, there was a high mean score across all the criteria. Thus, it can be inferred that a large percentage of the respondents confirmed that the criteria were critical to trust. The breakdown of each criteria response set is given in Table 5-1.

Table 5-1 Respondent data on how critical the criteria are to trust

	Minimum Statistic	Maximum Statistic	Mean Statistic	% Critical to trust
Adequate Service Policy	3	45	34.7241	77.17
Service Ease of Use	2	45	28.0690	62.38
Service Conflict Resolution	3	45	34.4138	76.48
Service Response to Deadlines	3	45	33.9828	75.52
Previous User's Inclination	2	45	25.3621	56.36
Service Quality	6	45	39.5000	87.78
Overall Service Evaluation	3	45	37.5345	83.41

In the above table, the minimum statistic refers to the lowest rating provided by respondents for that criterion (with lowest possible value = 0), while the maximum statistic refers to the highest rating provided by respondents for that criterion (with highest possible value = 45). From the data analysis, all the trust criteria have significant *critical-to-trust* response measures. However, it can be seen that when considering the criteria individually, the *service quality* trust criteria had the highest response (87.78%) of the *critical-to-trust* test, while the *previous user inclination* trust criteria had the lowest value (56.36%).

In determining the best method to use for default (system) trust criteria weights, the two methods previously described are considered. These are the pairwise comparison (relative) method default weights or the *critical-to-trust* method default weights. The critical-to-trust method for determining defaults is preferable as a result of the independent trust criteria assessment associated with the data collection instrument and analysis.

T-Tests, F-Tests and Analysis of Variance (ANOVA):

Usually, tests for significant differences are conducted to examine changes that occur over time or differences between groups or subgroups. The specific procedures that are used will depend on the type of measurement scale used for the survey items under scrutiny. Differences in categorical data, for example, may be analyzed using a procedure called X^2 (chi square) and differences in average (mean) scores may be analyzed using procedures such as the t-test or the analysis of variance test. By consensus, differences that are unlikely to be the result of chance fluctuations in the data alone (defined as a less than 0.05 probability) are referred to as *statistically significant*.

T-tests were also used to evaluate any statistical significance between the mean scores of two respondent or criteria groups (e.g. between the industry personnel group and between the students group or between different criteria mean sets). Thus, for the hypothesis:

$$H_o: \mu_D = 0$$

And alternate hypothesis,

$$H_a: \mu_D \text{ not equal to } 0$$

The results from analysis show if the t-value is larger than would be expected then the differences are due to chance. Results show that the differences between the industry group and the non-industry group (faculty and students) were more or less due to chance. With a 95% confidence interval, t-tests for pairwise comparisons among the criteria (21 pairs) were conducted with the following results summary (Detailed charts are presented in the Appendix):

The mean values of the criteria samples are not equal except for the (F1-F5), (F3-F5), (F4-F5) and (F6-F7) pairs.

From these results, the inference can be made that the Previous User Inclination trust criteria produced a similar response with the Adequate Service Policy, Service Conflict Resolution and Service Response to Deadlines criteria. Also the Service Quality trust criteria had the same mean response as the Overall Service Evaluation trust criteria.

Assuming equality of variance, ANOVA and F-tests were used in comparing three or more groups. From the survey design, users are required to rate the factors in relation to each other and also rate the factors in relation to the independent variable (trust).

The ANOVA test also offered a test of variance equality and a description of the nature of group differences. The means and standard errors were graphed and the bars represent the standard error of the means. The analysis of the graph does not show any trend in the means.

Hence, to test the equality of variance assumption, the ANOVA test is still performed, where the critical-to-trust value is the dependent variable and the criteria group is the factor variable. Using the descriptive and homogeneity of variance test statistics, ANOVA results were obtained as shown in Table 5-2 (a) – (c).

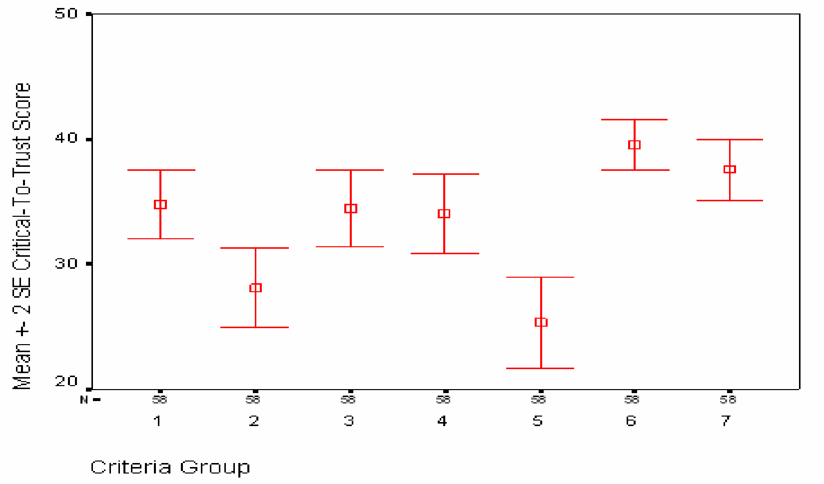


Figure 5-2 Graph of Means and Standard Errors

From the ANOVA results, the standard deviation and the standard error statistics confirm that trust criteria differ. The critical-to-trust values also differ. Table 5-2 (b) presents the test of homogeneity of variances, where the *Levene statistic* rejects the null hypothesis that the group variances are equal. Nevertheless, ANOVA is robust to this violation since the group sizes used in the test were equal.

Table 5-2 ANOVA Results

Oneway

Descriptives

Critical-To-Trust Score

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	58	34.7241	10.28675	1.35072	32.0194	37.4289	3.00	45.00
2	58	28.0690	12.21139	1.60343	24.8581	31.2798	2.00	45.00
3	58	34.4138	11.58649	1.52138	31.3673	37.4603	3.00	45.00
4	58	33.9828	11.92887	1.56634	30.8462	37.1193	3.00	45.00
5	58	25.3621	13.87121	1.82138	21.7148	29.0093	2.00	45.00
6	58	39.5000	7.85449	1.03134	37.4348	41.5652	6.00	45.00
7	58	37.5345	9.33249	1.22542	35.0806	39.9883	3.00	45.00
Total	406	33.3695	12.01528	.59631	32.1972	34.5417	2.00	45.00

(a)

Test of Homogeneity of Variances

Critical-To-Trust Score

Levene Statistic	df1	df2	Sig.
4.962	6	399	.000

(b)

ANOVA

Critical-To-Trust Score

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8725.892	6	1454.315	11.665	.000
Within Groups	49742.690	399	124.668		
Total	58468.581	405			

(c)

The significance value of the F-Test in the ANOVA table is 0.000. Thus, any hypothesis stating that the means are equal across the groups must be rejected and the *F* statistic establishes that there is a difference between group means, while mean plots (see Figure 5-3) show the structure of the differences between the means. Hence the means are significantly different.

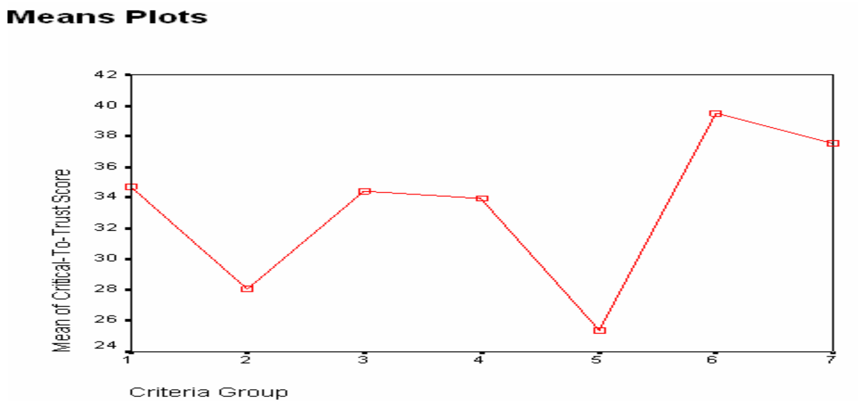


Figure 5-3 Means Plots for Trust Criteria

Multivariate Analysis (Regression):

In order to acquire a better trust estimate, it is also important to understand or determine the relationships between more than two variables. Linear regression models the value of a dependent scale variable based on its linear relationship to one or more predictors. For example, F1 and F7 present the following scatter plot in Figure 5-4.

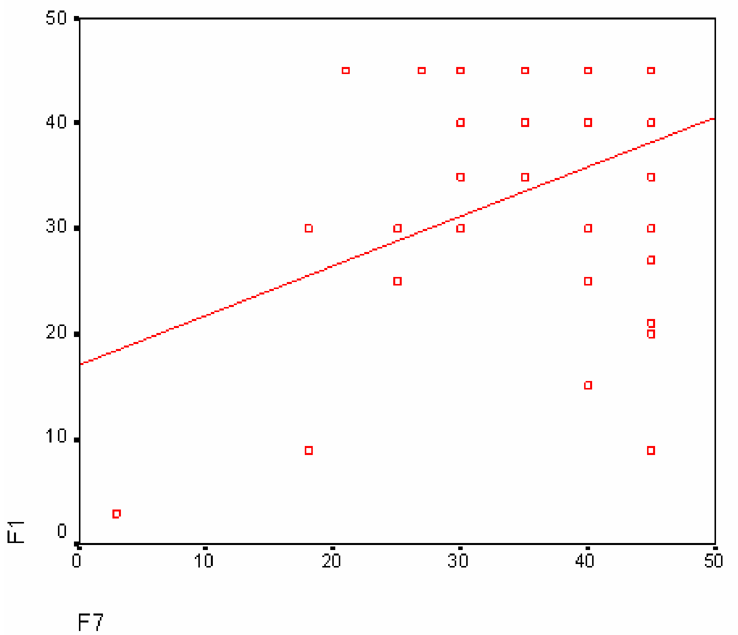


Figure 5-4 Scatter Plot

The scatter plot presents two concerns: the undue influence of an outlier and a trend of corresponding high values. However, regression analysis produced the following results shown in Table 5-3.

Table 5-3 Regression Coefficients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	24.054	3.966		6.066	.000
	F1	.388	.110	.428	3.543	.001

a. Dependent Variable: F7

Thus, from the above table, the expected value of F7 will be equal to 0.388 * F1 + 24.054. Another ANOVA table with respect to regression (see Table 5-4) tests the applicability of the above regression model from a statistical perspective.

Table 5-4 ANOVA for Regression

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	909.025	1	909.025	12.552	.001[a]
	Residual	4055.406	56	72.418		
	Total	4964.431	57			

a. Predictors: (Constant), F1

b. Dependent Variable: F7

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.428[a]	.183	.169	8.50987

a. Predictors: (Constant), F1

b. Dependent Variable: F7

The regression and residual sum of squares are not equal and indicate that the variation explained by the model is less than the variation that is not accounted for by the model. Also, the significant value of the F statistic is less than 0.05, which means that the variation explained by the model is not due to chance.

For the F1 and F7 model, *R*, the multiple correlation coefficient, indicates a positive correlation but does not indicate an exceedingly strong relationship (where an exceedingly strong relationship is defined in this research as values equal to or exceeding 0.7). *R Square*, the coefficient of determination and the squared value of the multiple correlation coefficient, shows that a very low percentage of the variation in F1 is explained by the model. Other comparisons among the trust criteria produced similar results.

Correlation Analysis:

Correlation results established a relationship between two variables, where correlation values range between +1 (positive correlation) and –1 (negative correlation). A value of 0 (zero) indicates no relationship between the variables.

Results from paired samples correlation analysis showed that some positive correlation exists between the all the pairs. However, the F5 (Previous User’s Inclination to Service) and F6 (Service Quality) had significantly correlated values.

Bivariate correlation data analysis was used to determine the strength and direction of the association between variables. Table 5-5 depicts the correlations between F1 and F2.

Table 5-5 Correlations between F1 and F2

Correlations

		Adequate Service Policy	Service Ease of Use
Adequate Service Policy	Pearson Correlation	1	.458**
	Sig. (2-tailed)	.	.000
	N	58	58
Service Ease of Use	Pearson Correlation	.458**	1
	Sig. (2-tailed)	.000	.
	N	58	58

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation reported in the table (0.458) is positive and suggests that the Service Ease of Use criteria has some effect on the Service Policy criteria and vice versa. However, the Pearson correlation coefficient works best when the variables are approximately normally distributed and have no outliers. Hence, a scatter plot is taken to reveal any potential problems. However, the scatter plot in Figure 5-5 does not show any apparent problem. Table 5-6 (a) depicts all the correlations between the criteria.

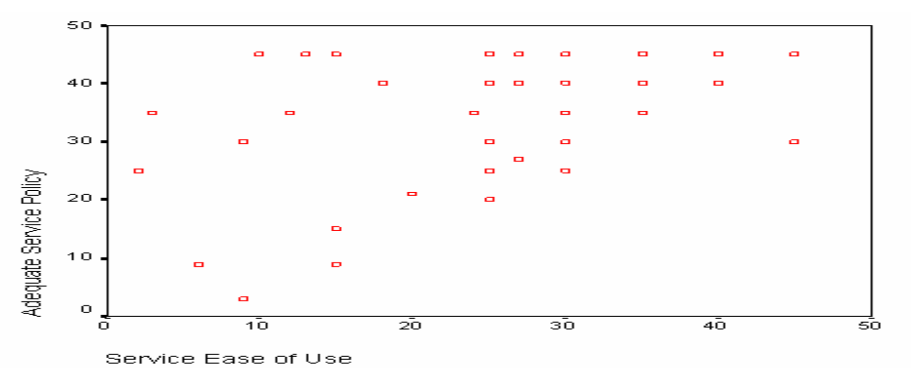


Figure 5-5 Scatter Plot for Adequate Service Policy and Service Ease of Use

Table 5-6 Correlations

Correlations

		F1	F2	F3	F4	F5	F6	F7
F1	Pearson Correlation	1	.458**	.583**	.565**	.425**	.494**	.428*
	Sig. (2-tailed)	.	.000	.000	.000	.001	.000	.001
	Sum of Squares and Cross-products	6031.586	3279.103	3957.621	3952.724	3458.793	2275.000	2341.552
	Covariance	105.817	57.528	69.432	69.346	60.681	39.912	41.080
	N	58	58	58	58	58	58	58
F2	Pearson Correlation	.458**	1	.546**	.439**	.611**	.201	.268*
	Sig. (2-tailed)	.000	.	.000	.001	.000	.131	.042
	Sum of Squares and Cross-products	3279.103	8499.724	4407.345	3647.069	5903.552	1098.000	1742.862
	Covariance	57.528	149.118	77.322	63.984	103.571	19.263	30.577
	N	58	58	58	58	58	58	58
F3	Pearson Correlation	.583**	.546**	1	.745**	.390**	.497**	.427*
	Sig. (2-tailed)	.000	.000	.	.000	.002	.000	.001
	Sum of Squares and Cross-products	3957.621	4407.345	7652.069	5868.414	3572.310	2576.000	2634.172
	Covariance	69.432	77.322	134.247	102.955	62.672	45.193	46.214
	N	58	58	58	58	58	58	58
F4	Pearson Correlation	.565**	.439**	.745**	1	.425**	.391**	.290*
	Sig. (2-tailed)	.000	.001	.000	.	.001	.002	.027
	Sum of Squares and Cross-products	3952.724	3647.069	5868.414	8110.983	4008.362	2087.500	1841.534
	Covariance	69.346	63.984	102.955	142.298	70.322	36.623	32.308
	N	58	58	58	58	58	58	58
F5	Pearson Correlation	.425**	.611**	.390**	.425**	1	.080	.270*
	Sig. (2-tailed)	.001	.000	.002	.001	.	.549	.041
	Sum of Squares and Cross-products	3458.793	5903.552	3572.310	4008.362	10967.397	498.500	1989.776
	Covariance	60.681	103.571	62.672	70.322	192.410	8.746	34.908
	N	58	58	58	58	58	58	58
F6	Pearson Correlation	.494**	.201	.497**	.391**	.080	1	.740*
	Sig. (2-tailed)	.000	.131	.000	.002	.549	.	.000
	Sum of Squares and Cross-products	2275.000	1098.000	2576.000	2087.500	498.500	3516.500	3091.500
	Covariance	39.912	19.263	45.193	36.623	8.746	61.693	54.237
	N	58	58	58	58	58	58	58
F7	Pearson Correlation	.428**	.268*	.427**	.290*	.270*	.740**	1
	Sig. (2-tailed)	.001	.042	.001	.027	.041	.000	.
	Sum of Squares and Cross-products	2341.552	1742.862	2634.172	1841.534	1989.776	3091.500	4964.431
	Covariance	41.080	30.577	46.214	32.308	34.908	54.237	87.095
	N	58	58	58	58	58	58	58

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

(a)

Table 5-6 (continued)

Nonparametric Correlations

Correlations

			F1	F2	F3	F4	F5	F6	F7
Spearman's rho	F1	Correlation Coefficient	1.000	.431**	.503**	.513**	.386**	.395**	.337**
		Sig. (2-tailed)	.	.001	.000	.000	.003	.002	.010
		N	58	58	58	58	58	58	58
	F2	Correlation Coefficient	.431**	1.000	.512**	.436**	.610**	.169	.239
		Sig. (2-tailed)	.001	.	.000	.001	.000	.204	.071
		N	58	58	58	58	58	58	58
	F3	Correlation Coefficient	.503**	.512**	1.000	.709**	.314*	.514**	.417**
		Sig. (2-tailed)	.000	.000	.	.000	.016	.000	.001
		N	58	58	58	58	58	58	58
	F4	Correlation Coefficient	.513**	.436**	.709**	1.000	.362**	.415**	.263*
		Sig. (2-tailed)	.000	.001	.000	.	.005	.001	.046
		N	58	58	58	58	58	58	58
	F5	Correlation Coefficient	.386**	.610**	.314*	.362**	1.000	-.016	.221
		Sig. (2-tailed)	.003	.000	.016	.005	.	.907	.096
		N	58	58	58	58	58	58	58
	F6	Correlation Coefficient	.395**	.169	.514**	.415**	-.016	1.000	.683**
		Sig. (2-tailed)	.002	.204	.000	.001	.907	.	.000
		N	58	58	58	58	58	58	58
	F7	Correlation Coefficient	.337**	.239	.417**	.263*	.221	.683**	1.000
		Sig. (2-tailed)	.010	.071	.001	.046	.096	.000	.
		N	58	58	58	58	58	58	58

**. Correlation is significant at the .01 level (2-tailed).

*. Correlation is significant at the .05 level (2-tailed).

(b)

Case Processing Summary

Cases					
Valid		Missing		Total	
N	Percent	N	Percent	N	Percent
58	95.1%	3	4.9%	61	100.0%

Proximity Matrix

	Correlation between Vectors of Values						
	F1	F2	F3	F4	F5	F6	F7
F1	.000	.458	.583	.565	.425	.494	.428
F2	.458	.000	.546	.439	.611	.201	.268
F3	.583	.546	.000	.745	.390	.497	.427
F4	.565	.439	.745	.000	.425	.391	.290
F5	.425	.611	.390	.425	.000	.080	.270
F6	.494	.201	.497	.391	.080	.000	.740
F7	.428	.268	.427	.290	.270	.740	.000

This is a similarity matrix

(c)

Using the correlations defined in this research as *highly* correlated at the 0.01 level (equal to or above 0.5). The DETS non-network criteria relationship matrix is shown in Table 5-7.

Table 5-7 DETS Non-Network Criteria Relationship Matrix

	F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**
F1			X	X			
F2			X		X		
F3	X	X		X			
F4	X		X				
F5		X					
F6							X
F7						X	

Analysis reveals the following associations:

F1: {F2, F3, F4, F5}

F2: {F1, F3, F4, F5}

F3: {F1, F2, F4, F5}

F4: {F1, F2, F3, F5}

F5: {F1, F2, F3, F4}

F6: {F7}

F7: {F6}

5.2 NETWORK DATA

The network Data Study was setup to demonstrate the objective nature and validity of network data such as estimated service response time, estimated wait time for a service or estimated service-processing time. Also reference is made to the 7 non-network trust criteria (adequate service policy, service ease of use, service conflict resolution, service response to deadlines, previous user's service inclination, service quality, overall service evaluation) and objective measurable data that can be acquired from subjective data. The non-network criteria were analyzed and connected to potential network measurable quantities or measurable components as shown in Table 5-8.

Table 5-8 Connecting Non-Network & Network Criteria

Non-Network Criteria	Potential Requirements	Potentially Measurable Network Components
Adequate service policy	Policy standards	-
Service ease of use	-	-
Service conflict resolution	Third parties	-
Service response to deadlines	Standards	Response time
Previous user's service inclination	-	-
Service quality	-	Quality of service routines
Overall service evaluation	-	-

Thus, it can be seen that certain network requirements need to be in place to obtain measurable components related to the non-network criteria. Nevertheless, other network data can still be collected and used to obtain a measurable estimate of trust for service. Three network data collection experiments were setup:

Experiment 1: *Service (File Transfer) Response Time*

Response time is a product of server performance and other factors. In conducting the network data experiment, a simulated Internet-based system (WAN) was set up using a simple response time calculator model, which allows for various parameters to affect response time including: 256 kbps WAN (Low congestion), busy server mode, idle server mode, client processing time, bandwidth etc. However, other parameters like error rates, lost packet rates etc. are not included in this experiment. A simple response time calculator model designed for demonstration purposes by RPM Solutions [110] was used in conducting this experiment.

Let:

Response Time = RT; Transmission Time = TT; Delays = D;

Client Processing Time = CPT; Server Processing Time = SPT

Where:

Transmission Time = *Data* to be transferred divided by *Bandwidth*

Delays = *Number of Turns* multiplied by '*Round Trip*' response time

Client Processing Time = Time taken (in ms) on client computer to fulfill request

Server Processing Time = Time taken (in ms) on server computer to fulfill request

The simplified formula for response time is given below:

$$RT = TT + D + CPT + SPT$$

The parameter descriptions are:

Data transfer for transaction: This is measured in kilobytes (KB). It is the size of the data file to be transferred

Effective Bandwidth: This is measured in kilobytes per second (kbps)

Round Trip Time: This is measured in milliseconds (ms). Round-Trip Time: This is an estimation of the longest time should take to exchange data packets especially when considering indefinitely large transfers, where *all* TCP implementations eventually drop packets and retransmit them, no matter how good the quality of the link

Number of Turns: In this research, this parameter is defined as the number of resources being requested through the service. For simplicity purposes, a value of 1 is used in this experiment

Response Time: This is the output value and is measured in seconds (s)

The following two tables present samples of data collected under different scenarios using the response time model mentioned previously.

Table 5-9 Response Time Experiment – Condition A

Condition: 256 kbps WAN - Busy Server							
No.	**Data Size (KB)**	**Client Processing Time (ms)**	**Server Processing Time (ms)**	**Effective Bandwidth (kbps)**	**Round Trip Time (ms)**	**# of turns**	**Estimated Response Time (s)**
1	49.7	30	31500	256	20	1	33.49
2	200	30	31500	256	20	1	39.36
3	675.3	30	31500	256	20	1	57.92
4	3,501.2	30	31500	256	20	1	168.31
5	32,921.1	30	31500	256	20	1	1317.53

Table 5-10 Response Time Experiment – Condition B

Condition: 256 kbps WAN - Idle Server							
No.	**Data Size (KB)**	**Client Processing Time (ms)**	**Server Processing Time (ms)**	**Effective Bandwidth (kbps)**	**Round Trip Time (ms)**	**# of turns**	**Estimated Response Time (s)**
1	49.7	30	80	256	20	1	2.07
2	200	30	80	256	20	1	7.94
3	675.3	30	80	256	20	1	26.5
4	3,501.2	30	80	256	20	1	136.89
5	32,921.1	30	80	256	20	1	1286.11

From the data collected, it can be seen that as the link becomes saturated or as processing time increases, response time for transactions that utilize the WAN link will degrade.

Experiment 2: *Using Network Data Collection Tools*

There are numerous network data collection tools available. Sample network data collection is given in Table 5-11 and Table 5-12.

Table 5-11 Network Tools Example: *Ping*

Ping		
No.	**Destination**	**Average Time Over 10 Pings (ms)**
1	69.31.48.17	6.3
2	136.142.42.14	63.1
3	63.216.25.136	7

Table 5-12 Network Tools Example: *TraceRoute*

TraceRoute		
No.	**Host**	
1	pittsburgh-supercomputing.so-2-1-1.ar3.jfk1.gblx.net	Success: 9 hops (62 milliseconds)
2	www.whitehouse.com	Failed (Timed Out/Aborted)
3	www.circuitcity.com	Success: 8 hops (9 milliseconds)

Experiment 3: *Data Analysis Experiment*

A finite element analysis (FEA) service experiment was setup up in which various data files were submitted for analysis and the time taken for complete analysis was recorded. FEA software includes software packages like ANSYS and ABAQUS. The experiment conducted involved locally resident analysis software with a Windows 2000 Professional, Gateway Inc. Intel ® Pentium processor 2.20 GHz system. Certain factors may affect the estimate data analysis run time such as computer's performance information such as millions of instructions per second (MIPS), millions of floating point operations per second (MFPOPS) and the number of iterations or load steps in a linear analysis. Figure 5-6 depicts a summary of ANSYS's run-time statistics, while Figure 5-7 shows the current system setting for runtime estimates.

Also, ABAQUS Computer Aided Engineering software provides a complete modeling and visualization environment. It allows for direct access to CAD models, advanced meshing and simultaneous data analysis. Figure 5-8 and Figure 5-9 also show different data models that were used in the experiment, while Figure 5-10 and Figure 5-11 depict a job submission dialog box.

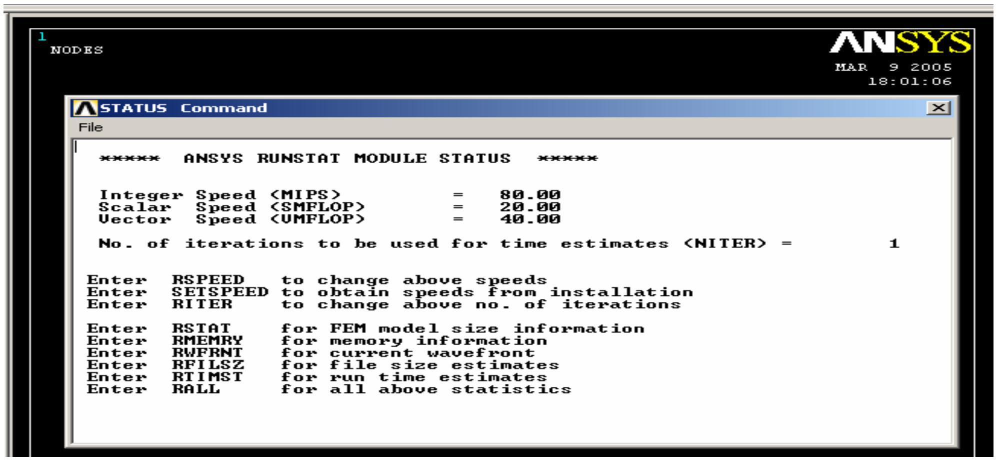


Figure 5-6 ANSYS Runtime Statistics Summary

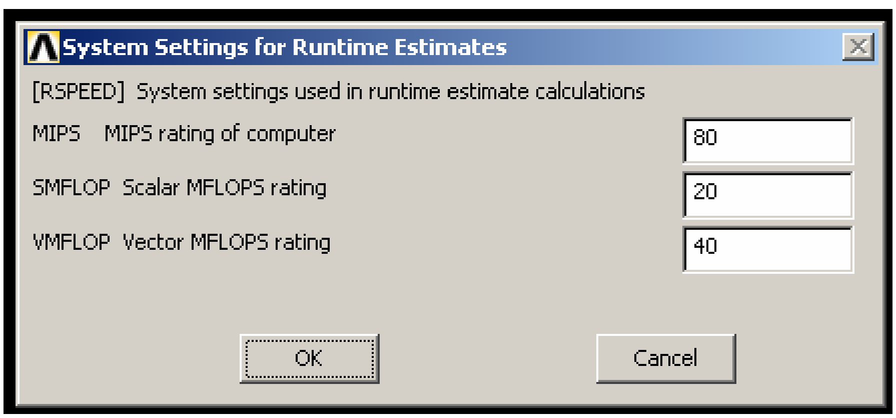


Figure 5-7 ANSYS System Settings for Runtime Estimates

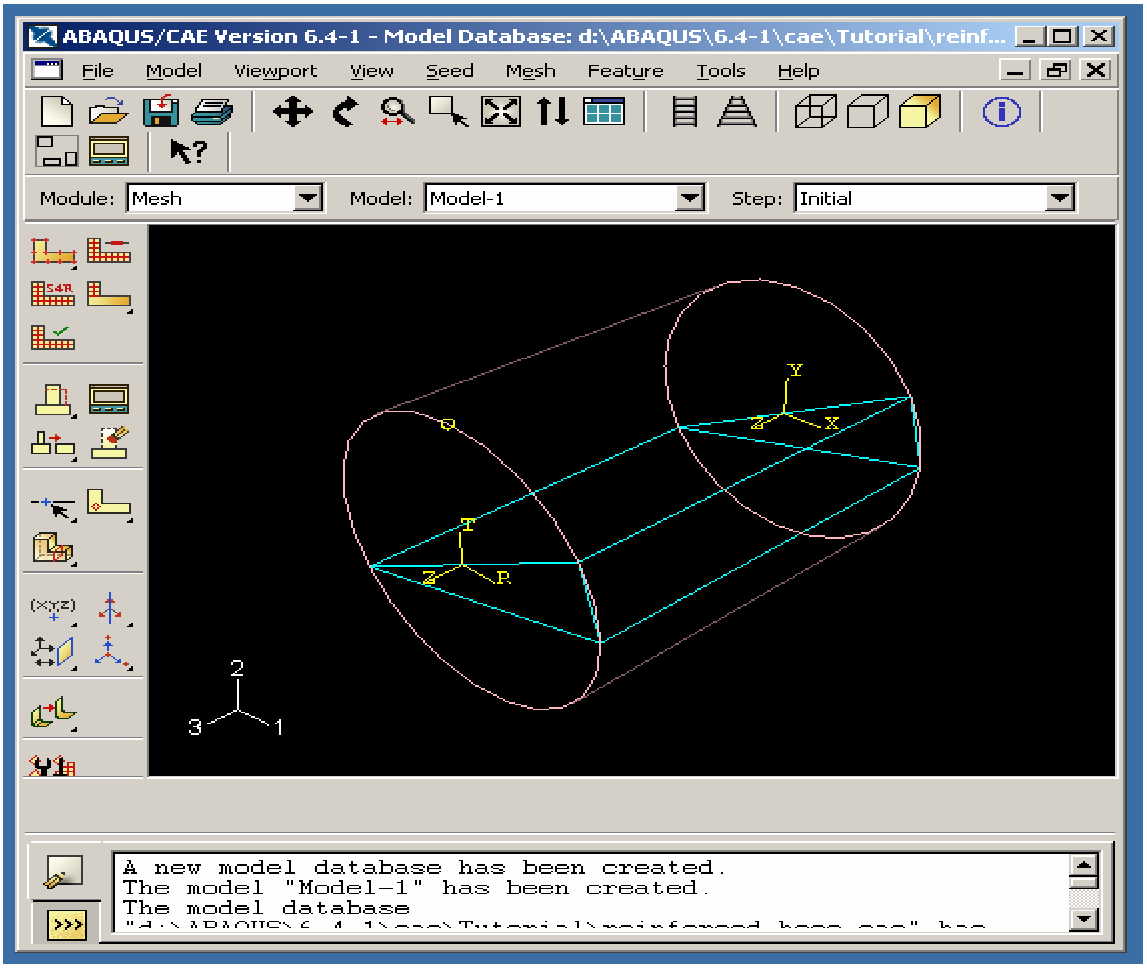


Figure 5-8 Reinforced Hose Data Model Assembly

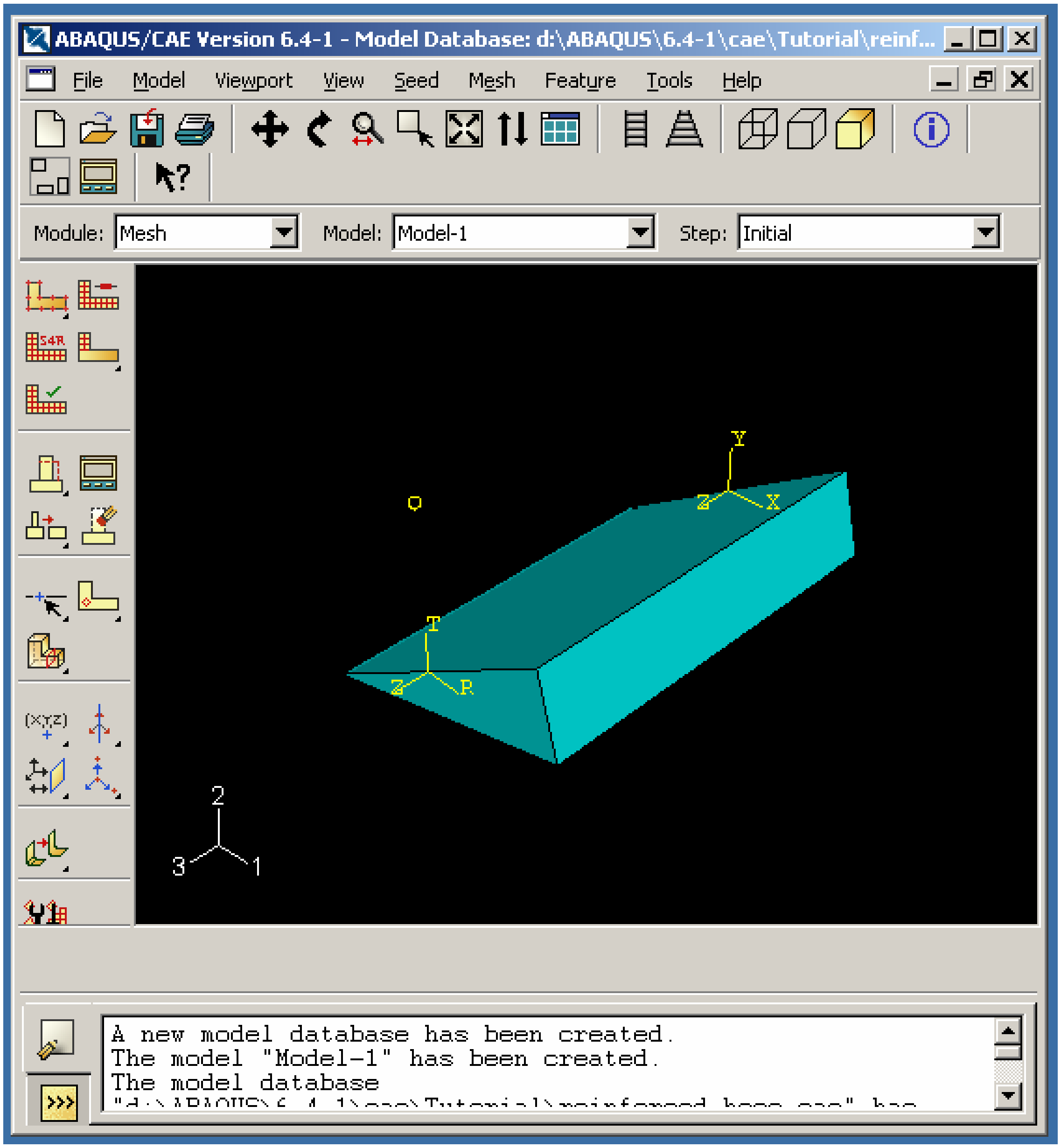


Figure 5-9 Reinforced Hose Data Model Part View

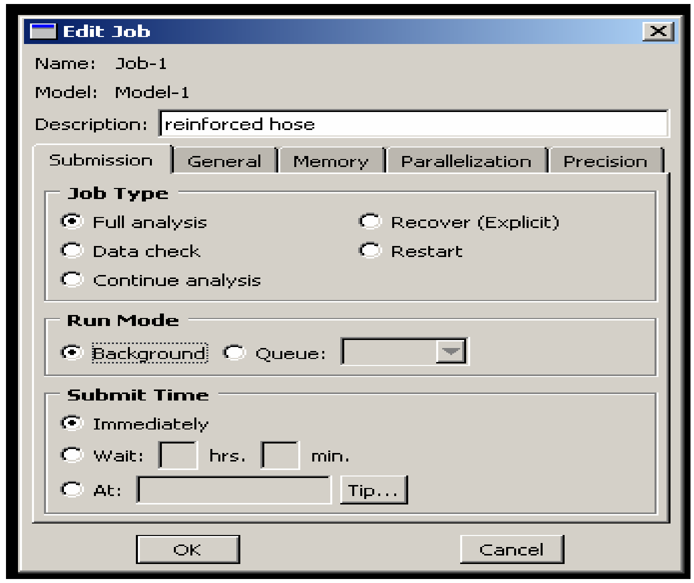


Figure 5-10 Data Analysis Job on ABAQUS 6.4

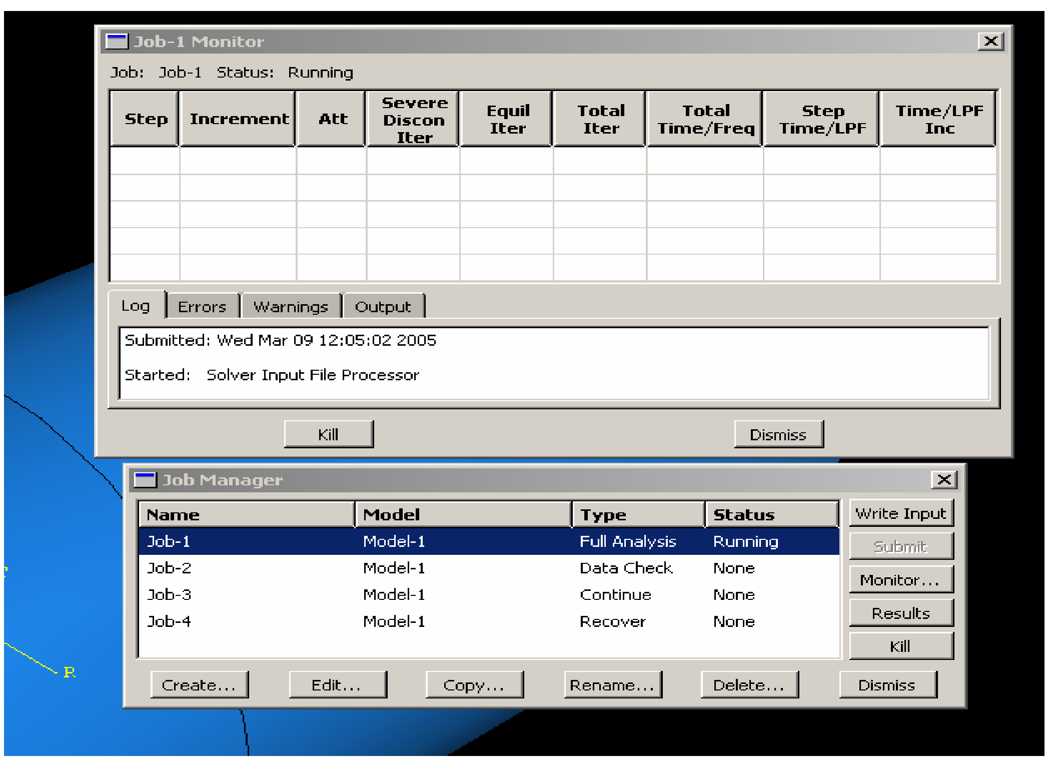


Figure 5-11Data Analysis Jobs

Hence, objective data can be obtained directly from the network. Such objective data collection is possible within the e-Design system even though for authenticity purposes, the data will need to undergo validation and maintenance routines in order to provide pragmatic use. Network data has also been used in similar cases to organize information and acquire knowledge. For example, Computer Associates et al [111] describe an eTrust Network Forensics system (Release 1.0) that captures raw network data and uses advanced forensics analysis to identify how business assets are affected by network exploits, internal data theft and security or policy violations.

Objective data and computations, which are based on this data, are used in deriving the Dynamic Trust Index (DTI). The DTI presents a rank or estimated measure of trust based on a distance from an ideal point.

5.3 COMPUTING THE DYNAMIC TRUST INDEX (DTI)

Non-network data such as user feedback and subjective recommendations have a significant role to play in service trustworthiness. Resnick et al [112] discuss the success of reputation-based systems, which have been implemented in e-commerce environments such as eBay and Amazon. Also, several reports have found that seller reputation has significant influences on on-line auction prices, especially for high-valued items [113] [114]. The reputation in an on-line community can be related to the ratings received from others [115] [116]. Resnick and Zeckhauser [117] have determined that feedback systems do encourage transactions. Also, network data can significantly influence service provider trustworthiness.

In computing the Dynamic Trust Index (DTI), a new Multi Criteria Decision Method approach, Combined Fuzzy and Non-Fuzzy Compromise Programming with Trust Penalty and Credit Adjustment, was developed based on two prior techniques, (i) the Compromise Programming (CP) approach initially introduced by Zeleny [118] to compare the performance of alternatives in a multi-objective decision problem and (ii) Fuzzy Compromise Programming investigated by Prodanovic and Simonovic [119]. Both techniques are represented by the equation below:

$$L_a = [\sum_{j=1}^{n} w^p_j |(Z^*_j - Z_j)/(Z^*_j - Z^-_j)|^p]^{1/p}$$

where:

j	= 1, 2, 3 . . . n and represent n criteria or objectives
a	= 1, 2, 3 . . . t and represents t alternatives
L_a	= distance metric of alternative a
W_j	= corresponds to a weight of a particular criteria or objectives
P	= compensation parameter (p = 1, 2, infinity)
Z^*_j and Z^-_j	= Z^*_j is the ideal value for the jth criteria (or objective) and Z^-_j is the anti-ideal value for the jth criteria (objective)
Z_j	= Z_j is the actual value of the jth criteria

Zeleny considered purely crisp numbers and Simonovic considered purely fuzzy numbers. However, the methodology discussed in this research builds on these two different perspectives. In order to compute a measure of trust through the Dynamic Trust Index, a detailed Design Environment Trust Service (DETS) framework was developed (flowchart shown in Figure 5-12), which incorporates objective (crisp) and subjective (fuzzy components). As a result of the real world vagueness of trust, the fuzzy component provides an adequate way of capturing vagueness due to imprecise data.

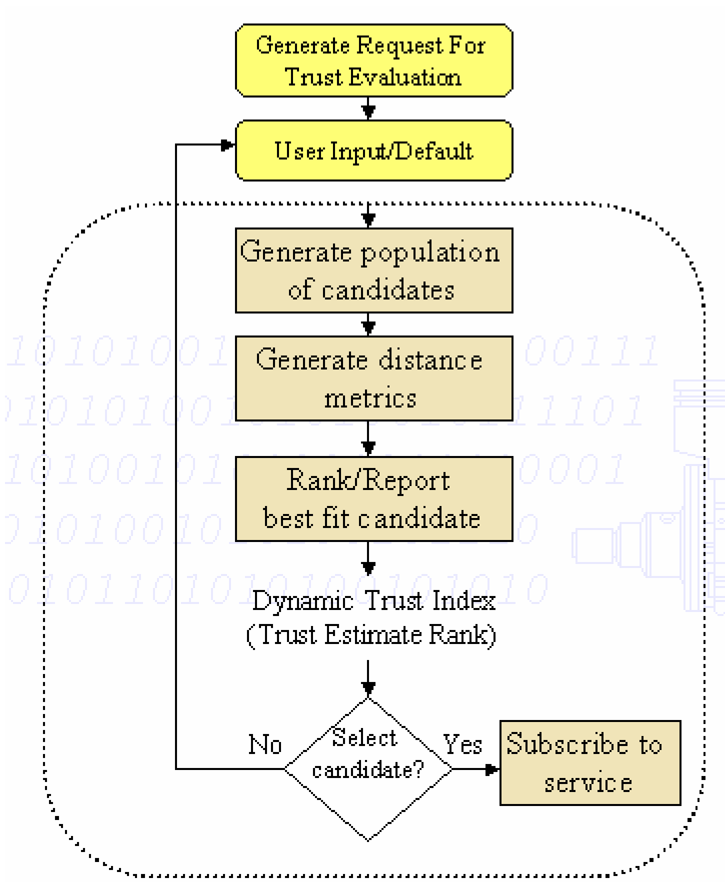


Figure 5-12 Design Environment Trust Service Flowchart

5.4 COMBINED FUZZY & NON-FUZZY COMPROMISE PROGRAMMING METHOD

In obtaining the Dynamic Trust Index (DTI), the DETS framework uses a Combined Fuzzy and Non-Fuzzy Compromise Programming with Trust Penalty and Credit Adjustment multi criteria optimization methodology. The method is mathematically represented by the following equation:

$$L_{a(x,\,y)} = [\sum_{j(x,y)=1}^{n1,n2} w^{p}_{j}\, |(Z^{*}_{j(x,\,y)} - Z_{j(x,\,y)}) + \Re_{j(y)})/(\,Z^{*}_{j(x,\,y)} - Z^{-}_{j(x,\,y)})|\,^{p}]^{\,1/p}$$

where,

x	= fuzzy subset
y	= non-fuzzy subset
j	= 1, 2, 3 . . . n and represent n criteria or objectives
a	= 1, 2, 3 . . . t and represents t alternatives
L_a	= distance metric of alternative a
W_j	= corresponds to a weight of a particular criteria or objectives
P	= compensation parameter (p = 1, 2, infinity)
Z^{*}_{j} and Z^{-}_{j}	= Z^{*}_{j} is the ideal value for the jth criteria (or objective) and Z^{-}_{j} is the anti-ideal value for the jth criteria (objective)
Z_j	= Z_j is the actual value of the jth criteria
$\Re_y$	= non-fuzzy adjustment factor

There is a combined calculation of network and non-network distance metrics, where *x* represents the fuzzy subset and *y* represents the non-fuzzy subset. The weights (*w*) could be system (default) weights or weights particularly specified by the decision maker. The *p* parameter denotes a compensation factor. A *p* value of one is used to demonstrate that equal compensation is applied to the trust criteria. Z^*_j is the ideal value for the jth criteria (or objective) and Z^-_j is the anti-ideal value for the jth criteria (objective), while Z_j is the actual value of the jth criteria. $\Re_y$ represents a non-fuzzy adjustment factor which could be a penalty or a credit.

Data on trust adjustments need to be collected periodically in order to update information within the framework. Hence, a weighted average system is adopted to provide a pragmatic solution to the dynamic nature of the data in the system. A yearly reassessment of data is recommended for updating data.

The DETS framework makes use of data from two primary sources: (a) Network data, which is defined as non-fuzzy data for the purposes of this research, and (b) Non-network data, which is defined in this research as fuzzy data. The main idea of the methodology minimizes uncertainty while accounting for it at the same time.

Hence, data that has been acquired by the system with minimal (acceptable) or no subjective influence is maintained as "non-fuzzy" data. This technique is different from previous related methods, which fuzzify all the data, thereby increasing the amount of uncertainty in the system.

Hence, the Non-Fuzzy Compromise Programming component of the methodology is used to address the objective data.

Nevertheless, because of the subjective criteria included in the model, determining trustworthiness presents a departure from classical two-valued sets and logic that use strict 0 or 1 decisions and assignments. Hence, fuzzy logic, which allows for partial memberships, is applied. Fuzzy logic has useful applications in control systems, information systems, pattern recognition and decision support. Key benefits of fuzzy designs include user-friendly and efficient performance, ease of implementation and simplified & reduced development cycle.

The DETS framework uses fuzzy logic as a structured, model-free estimator that approximates a function through natural language input/output associations. The fuzzy controller used in this research involves the determination of a fuzzy rule base, membership functions and an inference procedure.

In the literature, no standard method exists for creating membership functions. Membership values in fuzzy sets are indicated by a value on the range [0.0, 1.0], with 0.0 representing *absolute falseness* and 1.0 representing *absolute truth*.

The DETS model uses weights on the criteria, which could be specified by the system, set to be equal across all criteria or specified by the user. Also as a result of the data input, certain inputs may be considered as red flags or unacceptable within the model. This is especially possible with the fuzzy input data. Based on the fuzzy rule sets established, these data anomalies are *normalized* by adjustment. In this context, normalization is defined as the process by which the data is transformed from an *unacceptable status* (red flag status) to the *closest or least acceptable status*. The transformed data is then transferred into the DETS knowledge base. The objective of the adjustment module is to minimize errors in the fuzzy decision making process, introduce some measure of data consistency, eliminate bias (or unacceptable outliers) and ultimately reduce fuzziness.

Trust Penalty and Credit Adjustments

In order to incorporate data balance within the e-Design service provision selection system, a distinctive process of adjustments are incorporated into the trust measure computation system.

Examples of some reasons regarding the need for adjustments are given below:

- Services from service providers may realistically have unequal numbers of data entry records. For example, Service Provider X has 4500 validated records, while Service Provider Y (who provides the same service as X) has only 32 records. Thus, Service Provider X receives credit for having a greater history;
- Service Provider Z has been consistently offline for a considerable amount of time (e.g 15 days out of the last 60 days) even though other validated objective data remain impressive. Thus, a penalty should be applied in this case;
- Also as a result of certain trust criteria associations, data may need to get transformed and such transformations need to be accounted for in the computations;

The adjustment parameter ($\Re$) is categorized as either a trust penalty (-) or a trust credit (+). An example of a trust penalty adjustment is the *Red Flag Penalty*. An example of a trust credit adjustment is the *History Credit*. Other adjustments discussed in this documentation include the *Low Trust Penalty* and the *High Trust Credit*.

Red Flag Penalty & Rule Base

Table 5-13 shows a sample of non-network criteria data (F1 – F7) and network criteria data (service response time in seconds). This data is for 5 potential service providers, where the non-network criteria values range from 0 (Lowest) to 10 (Highest). The high scores set (High) is defined as {7, 8, 9 and 10}, the medium scores set (Medium) is {4, 5 and 6} and the low scores set (Low) is {0,1,2,3}. Thus, Service Provider 1 (SP1) with a score of 3 for F2 would imply that the client believes that SP1's Service Ease of Use is low, though not *too low*.

However, defining "too low" is somewhat subjective. Figure 5-13 aptly describes this scenario using a natural language slider along with numerical values. The range could also be interpreted as: *Very Poor* [0], *Poor* [3], *Ok* [5], *Good* [7], *Very Good* [10]. Here, 3 falls of within the *'poor'* region, though not too far from the *'very poor'* region. How far is too far? Nevertheless, it still remains subjective.

Table 5-13 Sample of Non-Network and Network Data for 5 Service Providers

	F1	F2	F3	F4	F5	F6	F7	Service Response Time (seconds)
Service Provider 1 (SP1)	6	3	6	4	7	1	10	2312
Service Provider 2 (SP2)	9	9	3	7	5	5	3	3212
Service Provider 3 (SP3)	10	2	3	1	6	7	5	1002
Service Provider 4 (SP4)	1	2	6	2	5	3	2	699
Service Provider 5 (SP5)	3	10	10	3	2	6	4	1865

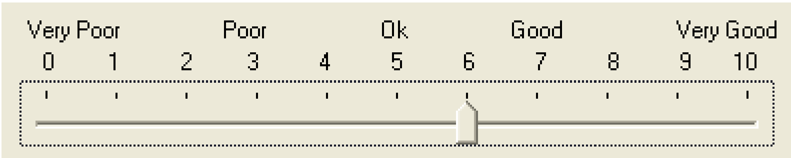


Figure 5-13 Non-Network Data Linguistic Entry Sample

As can be seen from Service Provider 1, there is a perfect membership for the positive rating of the "Overall Service Evaluation" criterion. However, the "Service Quality" criterion depicts a near perfect membership for the poor rating. This does not seem like a logical outcome. Also, recalling form the non-network criteria relationship summary previously presented, F6 and F7 have a relationship. Hence, there is a need to identify and establish fuzzy rules to help in obtaining appropriate inferences about the data.

Obviously, it can be seen that optimal and worse values for each criteria can be readily identified. Thus, if Service Provider K had the following non-network data:

	F1	F2	F3	F4	F5	F6	F7
SP1	10	10	10	10	10	10	10

This would be the best rating available. Also if Service Provider P has the following non-network data:

	F1	F2	F3	F4	F5	F6	F7
SP1	0	0	0	0	0	0	0

This would be the worst score available. The best/worst data information aids in the determination of fuzzy rule sets. Since weights may be applied to the criteria and weights must sum up to 1, the maximum resulting *data value* (V) a trust criterion can take on is 1 * 10 = 10. If the weight for F1 is 0.45, then maximum V = 0.45 * 10 = 4.5.

Even though the criteria are termed independent, low scores in certain criteria logically should not allow a high score in certain other criteria as was seen in the data analysis. Nevertheless, the criteria composition was set up to allow for flexibility in the selection of specific trust evaluation criteria. However, the trust criteria relationships matrix data is used in determining the rules associated with data transformation. The summary is given below:

F1: {F3, F4} → F1 is associated with F3 and F4

F2: {F3, F5} → F2 is associated with F3 and F5

F3: {F1, F2, F4} → F3 is associated with F1, F2 and F3

F4: {F1, F3} → F4 is associated with F1 and F3

F5: {F2} → F5 is associated with F2

F6: {F7} → F6 is associated with F7

F7: {F6} → F7 is associated with F6

Combining related associations:

F1: {F2, F3, F4, F5}

F2: {F1, F3, F4, F5}

F3: {F1, F2, F4, F5}

F4: {F1, F2, F3, F5}

F5: {F1, F2, F3, F4}

F6: {F7}

F7: {F6}

Thus, there is a tangible association between F1, F2, F3, F4 and F5. On the other hand, F6 and F7 also have a tangible association. Therefore, the following rules were developed to *normalize* the data before it is used for computation. Normalization accounts for inconsistencies as determined by the trust data analysis. In this aspect of the research, these data inconsistencies are referred to as *red flags*.

Let c and d = the criteria subscripts

For example, if c = 2, then $F_c = F_2$ = Service Ease of Use

Then RULE 1 is defined thus:

```
FOR c = 1 TO 5
    Count = 0
    FOR d = 1 TO 5
        Criteria_Value_Set = F_d
        IF (Fc => 7) AND (F_d <=3) THEN Count = Count + 1
    END
    IF Count = 4 THEN (Fc = max(Criteria_Value_Set )
END
```

This rule ensures that since these criteria have the above stated association, then there is a consistent data entry within the network. RULE 1 can also be restated thus:

RULE 1: IF (F_c => 7) AND (F_D <= 3) THEN (F_c = max(F_D)

Where the "D" subscript represents the set of other criteria excluding F_c.

RULE 2 is the contrary to RULE 1:

RULE 2: IF (F_c <= 3) AND (F_D >= 7) THEN (F_c = min(F_D)

Also, from the relationship table, it can be seen that F6 ia associated with F7. Hence, RULE 3 becomes:

RULE 3: WHILE |[Criteria_Value(F6)] - [Criteria_Value(F7)]| > 3

DO max(Criteria_Value(F_c) = max(Criteria_Value(F_c) – 3

The values of 3 and 7 were used in establishing the ruleset because of the trend in the data and the responses of respondents. The fuzzy criteria more or less fell into three groups: good, ok or bad. Hence the use of 3, which implies 3 values from the bottom or the use of 7, which implies 3 values from the top.

Thus, the values obtained below indicate a red flag entry with respect to F6 & F7:

	F1	F2	F3	F4	F5	F6	F7
SP1	2	1	2	3	2	**0**	**10**

Applying RULE 3, the transformed entry becomes:

	F1	F2	F3	F4	F5	F6	F7
SP1	2	1	2	3	2	**0**	**3**

The need and effect of this transformation becomes more apparent when a decision maker specifies certain trust criteria for assessment. Table 5-14 presents the transformed data for the 5 service providers.

Table 5-14 Transformed Non-Network Data for 5 Service Providers

	F1	F2	F3	F4	F5	F6	F7	Min	Max
SP1	6	3	6	4	7	1	4	1	7
SP2	9	9	3	7	5	5	3	3	9
SP3	10	2	3	1	6	7	5	1	10
SP4	1	2	6	2	5	3	2	1	6
SP5	3	10	10	3	2	6	4	2	10

A penalty representing the number of red flag entry adjustments is applied to the DTI computation.

Red Flag Penalty Adjustment = (# of Transformations)/(# of Independent Entries)

For example, if the trust evaluation period is the last 3 months and Service Provider Z has 3,215 independent and validated records with 450 adjustments in the last three months, then the Red Flag Penalty Adjustment within this period is 450/3215 = 0.14. If Service Provider Y has 1 independent and validated record with 1 adjustment in the last three months, then the Red Flag Penalty Adjustment within this period is 1/1 = 1.

Low Trust Penalty & High Trust Credit Adjustments

Recalling the previous fuzzy value classifications: High scores set (High) are defined as {7, 8, 9and 10}, medium scores set (Medium) are {4, 5 and 6} and low scores set (Low) are {0,1,2,3}. Using the High, Medium and Low fuzzy values, a fuzzy variable defined as Fuzzy_Decision and trust classifications defined as HIGH_TRUST, MEDIUM_TRUST and LOW_TRUST, the following rules are developed:

RULE 4:

IF (F1, F2, F3, F4, F5, F6 and F7) = High THEN Fuzzy_Decision is High_Trust

This is interpreted as: If all of the criteria values (F1 to F7) are in the high range, then the record is categorized as HIGH_TRUST.

RULE 5 is the contrary of RULE 4.

RULE 5:

IF (F1, F2, F3, F4, F5, F6 and F7) = Low THEN Fuzzy_Decision is Low_Trust

RULE 6:

IF (F1, F2, F3, F4, F5, F6 and F7) = Medium THEN Fuzzy_Decision is Medium_Trust

The High Trust Credit Adjustment is defined as:

High Trust Credit = 3 *[(# of HIGH_TRUST entries)/# of entries)]

The Low Trust Penalty Adjustment is defines as:

Low Trust Penalty = (# of LOW_TRUST entries)/# of entries)

Thus, if Service Provider A in say the last 3 months, has 2000 entries and 350 of the entries fall into the HIGH_TRUST and 350 of the entries fall into the LOW_TRUST, then:

High Trust Credit = 3 *(350/2000) = 0.525

Low Trust Penalty = 350/2000 = - 0.175

The penalty is represented as a negative value, while the credit is presented as a positive value. At this time, MEDIUM_TRUST entries will not be considered for adjustment purposes.

Tie Breaker Rules

Other failsafe rules that come into play in the case of a DTI service provider tie, uses the Best_Fit fuzzy variable:

RULE 10: IF Max(j) > Max(k) THEN Best_Fit = j ELSE Best_Fit = k

Where j and k are the service providers alternatives being compared. If the max values are identical, then RULE 11 is used.

RULE 11: IF Min(j) > Min(k) THEN Best_Fit = j ELSE Best_Fit = k

These composition rules form the fuzzy rule base for the inference engine.

History Credit

If Service Provider A has existed within the network longer than another service provider being compared, Service Provider A can apply a history credit adjustment based on the outcomes of previous service provision transactions

DETS fuzzy weights and ideal/worst values

Default (system) non-network trust criteria weights were determined using the Analytical Hierarchy Process (AHP) process discussed in the data analysis section. However, the DETS framework incorporates flexibility by allowing the decision maker determine or specify other criteria weights.

Ideal and worst case values may also be determined by the decision maker prior to the Request For Trust Evaluation (RFTE). However, in the absence of any user specified values, the system default values will be the used: 0 for worst case (non-network criteria) and 10 for ideal case (non-network criteria). For network criteria, in the absence of decision-maker specified values, benchmark or extreme-end values may be used.

DETS Non-Network Component Fuzzification

The DETS Fuzzy Component consists of:

- *Natural language (linguistic) variables:* approximate terms describing measurements on the system parameters e.g. poor, good, ok, not sure, yes, no. Numerical values are also used in this model to decrease fuzziness;
- *Membership functions (fuzzification functions)*: membership functions determine by how much a variable say X belong to different regions of a natural language variable say Q. The functions specify the degree of membership of a measurement in a fuzzy concept represented by a natural language variable

For example, if Q is a natural language variable e.g. *"good"* and X is a crisp value describing the level, then the membership function can be represented by:

M((q)(x)) = 0, which means that x is not equal to q

Also, M((q)(x)) = 0.6, means that x = q with a degree of 0.6

M((q)(x)) = 1, which means that x = q

If another natural language function R is defined, it is possible that:

M((q)(x)) = 0.6, which means that x = q with a degree of 0.6

And M((r)(x)) = 0.1, which means that x = r with a degree of 0.1

- '*Rule base*: this is a collection of rules that collectively specify the non-network data entry with the syntax:

  <antecedent> → <consequent>

The fuzzy criteria data are transformed into a fuzzy set by changing all the inputs through the application of the fuzzy extension principle, which defines how a value, function or set can be represented by a corresponding fuzzy membership function. The inputs for the non-network section of the model are acquired from existing service user data and feedback and are based on established non-network data parameters.

The fuzzification process determines the membership functions of natural language variables and describes the behaviour of the sets. Fuzzification of the criteria values enables the preservation of information based on a subjective point of view. Where one client may consider a service's ease of use "neutral", another may consider it "somewhat easy". Since the client cannot represent “somewhat easy” and a wide variety of other potential responses on the input scale, fuzzy theory is used to adjust for the lack of crispness.

Also, even if the subjectivity level of the model input were acceptable, it is still a good idea to maintain the fuzzification routines in order to account for potential lack of completeness associated with the trust criteria values themselves.

The DETS framework membership functions are assumed to be triangular in shape. Using the non-network trust criteria established during the course of this work, Table 5-15 depicts the natural language (linguistic) variables and membership function used in the computation.

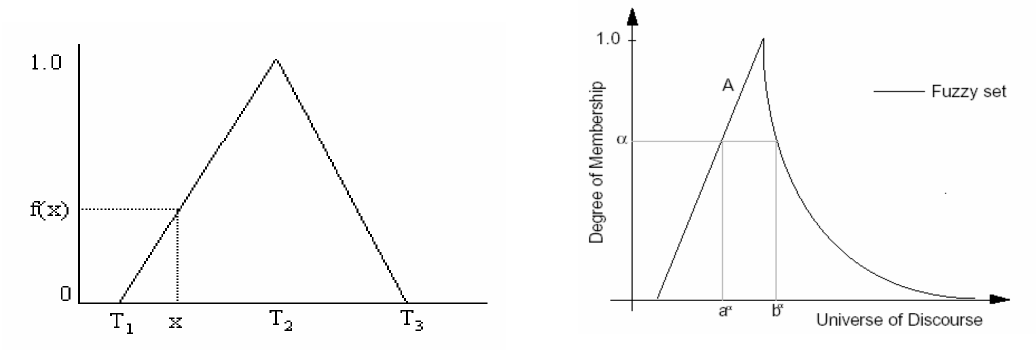
Membership functions were created based on the conducted surveys, ‘eyeball’ estimations and other methods including inductive reasoning [120], direct rating and polling.

The range of 0 to 10 was used in all cases based on frequency of results. It is important to note that subsequent model upgrades and future research extensions may increase or reduce the established non-network trust criteria.

Table 5-15 Linguistic Variables

Criteria	Membership Range	Simple Linguistic Variables	Expanded Linguistic Variables
F1: Adequate Service Policy	[0, 10]	*Yes* [10] *No* [0]	*Highly Adequate* [10] *Somewhat Adequate* [7] *Neutral* [5] *Somewhat Inadequate* [3] *Highly Inadequate* [0]
F2: Service Ease of Use	[0, 10]	*Easy* [10] *Neutral* [5] *Difficult* [0]	*Very Easy* [10] *Easy* [7] *Neutral* [5] *Difficult* [3] *Very Difficult* [0]
F3: Service Conflict Resolution	[0, 10]	*No Conflict* [10] *Conflict/Resolved* [5] *Conflict/Unresolved* [0]	*No Conflict* [10] *Conflict/Resolved* [5] *Conflict/Unresolved* [0]
F4: Service Response to Deadlines	[0, 10]	*Prompt* [10] *Ok* [5] *Delayed* [0]	*Very Prompt* [10] *Prompt* [7] *Ok* [5] *Minor Delay* [3] *Major Delay* [0]
F5: Previous User Inclination	[0, 10]	*Yes* [10] *Not Sure* [5] *No* [0]	*Yes* [10] *Maybe Yes* [7] *Neutral* [5] *Maybe No* [3] *No* [0]
F6: Service Quality	[0, 10]	*Very Good* [10] *Ok* [5] *Poor* [0]	*Very Good* [10] *Good* [7] *Ok* [5] *Poor* [3] *Very Poor* [0]
F7: Overall Service Evaluation	[0, 10]	*Positive* [10] *Neutral* [5] *Negative* [0]	*Very Positive* [10] *Positive* [7] *Neutral* [5] *Negative* [3] *Very Negative* [0]

Let T represent the triangular fuzzy numbers into which the criteria values are fuzzified. Triangular fuzzy number representations are shown in Figure 5-14 (a) and (b). In part (b) of the figure, α specifies the degree of membership on the y-axis while a^{α} and b^{α} are intervals on the x-axis.



(a) (b)

Figure 5-14 Triangular Fuzzy Number Representations

Therefore, T is defined by the triple (T1, T2, T3) with membership function:

T = (T1, T2, T3)

M(T, x) = 0 for x < T1

M(T, x) = (x-T1)/(T2-T1) for T1 <= x <= T2

M (T, x) = (T3 – x)/(T3-T2) for T2 <= x <= T3

M(T, x) = 0 for x > T3

Triangular fuzzy numbers enable manipulation in real space. The triangle is normalized in the vertical direction so that membership values are between 0.0 and 1.0. Using consistent triangular fuzzy numbers across the non-network criteria results in the classifications given in Table 5-16.

Table 5-16 Triangular Fuzzy Number Classifications

Non-Network Criteria	Extended Linguistic Variables	Triangular Fuzzy Numbers
F1: Adequate Service Policy	*Highly Adequate* [10] *Somewhat Adequate* [7] *Neutral* [5] *Somewhat Inadequate* [3] *Highly Inadequate* [0]	(8, 9, 10) (6, 7, 8.5) (4, 5, 6.5) (1.5, 3, 4.5) (0, 1, 2)
F2: Service Ease of Use	*Very Easy* [10] *Easy* [7] *Neutral* [5] *Difficult* [3] *Very Difficult* [0]	(8, 9, 10) (6, 7, 8.5) (4, 5, 6.5) (1.5, 3, 4.5) (0, 1, 2)
F3: Service Conflict Resolution	*No Conflict* [10] *Minor Conflict/Resolved* [7] *Major Conflict/Resolved* [5] *Conflict/Partially Resolved* [3] *Conflict/Unresolved* [0]	(8, 9, 10) (6, 7, 8.5) (4, 5, 6.5) (1.5, 3, 4.5) (0, 1, 2)
F4: Service Response to Deadlines	*Very Prompt* [10] *Prompt* [7] *Ok* [5] *Minor Delay* [3] *Major Delay* [0]	(8, 9, 10) (6, 7, 8.5) (4, 5, 6.5) (1.5, 3, 4.5) (0, 1, 2)
F5: Previous User Inclination	*Yes* [10] *Maybe Yes* [7] *Neutral* [5] *Maybe No* [3] *No* [0]	(8, 9, 10) (6, 7, 8.5) (4, 5, 6.5) (1.5, 3, 4.5) (0, 1, 2)
F6: Service Quality	*Very Good* [10] *Good* [7] *Ok* [5] *Poor* [3] *Very Poor* [0]	(8, 9, 10) (6, 7, 8.5) (4, 5, 6.5) (1.5, 3, 4.5) (0, 1, 2)
F7: Overall Service Evaluation	*Very Positive* [10] *Positive* [7] *Neutral* [5] *Negative* [3] *Very Negative* [0]	(8, 9, 10) (6, 7, 8.5) (4, 5, 6.5) (1.5, 3, 4.5) (0, 1, 2)

A graphical representation is shown in Figure 5-15. For example, the value 6 belongs to Region 3 with 0.3 membership (R3, 0.3) and is represented as an interval by tracing the membership function lines to the x-axis. Hence, the value 6 is represented by the [4.5, 6] interval.

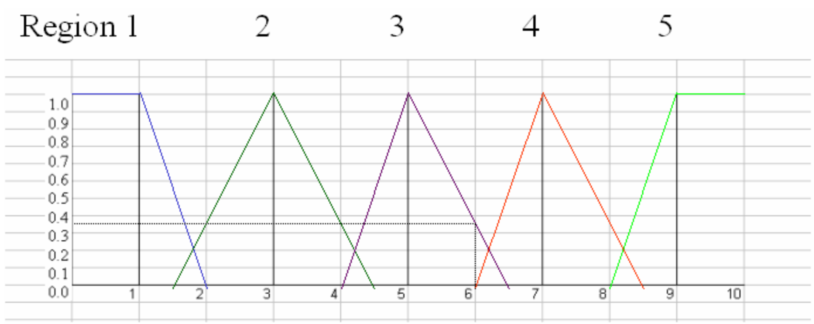


Figure 5-15 Membership Function Graph

The interval arithmetic definitions are:

Addition: [a, b] + [d, e] = [a + d, b + e]

Subtraction: [a, b] - [d, e] = [a - e, b - d]

Multiplication: [a, b] * [d, e] = [min(ad, ae, bd, be), max(ad, ae, bd, be)]

Power: $[a, b]^{[d, e]} = [\min(a^d, a^e, b^d, b^e), \max(a^d, a^e, b^d, b^e)]$

Division: [a, b] / [d, e] = [min(a/d, a/e, b/d, b/e), max(a/d, a/e, b/d, b/e)], provided that $0 \notin [d, e]$

Using the transformed data for the 5 service providers, the data is represented as regions in shown below:

	F1	F2	F3	F4	F5	F6	F7
SP1	R3, 0.3	R2, 1.0	R3, 0.3	R2, 0.3	R4, 1.0	R1, 1.0	R2, 0.3
SP2	R5, 1.0	R5, 1.0	R2, 1.0	R4, 1.0	R3, 1.0	R3, 1.0	R2, 1.0
SP3	R5, 1.0	R2, 0.3	R2, 1.0	R1, 1.0	R3, 0.3	R4, 1.0	R3, 1.0
SP4	R1, 1.0	R2, 0.3	R3, 0.3	R2, 0.3	R3, 1.0	R2, 1.0	R2, 0.3
SP5	R2, 1.0	R5, 1.0	R5, 1.0	R2, 1.0	R2, 0.3	R3, 0.3	R2, 0.3

	F1	F2	F3	F4	F5	F6	F7
SP1	{0,0,0.3,0,0}	{0,1.0,0,0,0}	{0,0,0.3,0,0}	{0,0.3,0,0,0}	{0,0,0,1.0,0}	{1.0,0,0,0,0}	{0,0.3,0,0,0}
SP2	{0,0,0,0,1.0}	{0,0,0,0,1.0}	{0,1.0,0,0,0}	{0,0,0,1.0,0}	{0,0,1.0,0,0}	{0,0,1.0,0,0}	{0,1.0,0,0,0}
SP3	{0,0,0,0,1.0}	{0,0.3,0,0,0}	{0,1.0,0,0,0}	{1.0,0,0,0,0}	{0,0,0.3,0,0}	{0,0,0,1.0,0}	{0,0,1.0,0,0}
SP4	{1.0,0,0,0,0}	{0,0.3,0,0,0}	{0,0,0.3,0,0}	{0,0.3,0,0,0}	{0,0,1.0,0,0}	{0,1.0,0,0,0}	{0,0.3,0,0,0}
SP5	{0,1.0,0,0,0}	{0,0,0,0,1.0}	{0,0,0,0,1.0}	{0,1.0,0,0,0}	{0,0.3,0,0,0}	{0,0,0.3,0,0}	{0,0.3,0,0,0}

Converting to intervals:

	F1	F2	F3	F4	F5	F6	F7
SP1	[4.5, 6]	[2, 4]	[4.5, 6]	[2, 4]	[7, 7]	[1, 1]	[2, 4]
SP2	[9, 10]	[9, 10]	[2, 4]	[7, 7]	[5, 5]	[5, 5]	[2, 4]
SP3	[10, 10]	[2, 4]	[2, 4]	[1, 1]	[4.5, 6]	[7, 7]	[5, 5]
SP4	[1, 1]	[2, 4]	[4.5, 6]	[2, 4]	[5, 5]	[2, 4]	[2, 4]
SP5	[2, 4]	[10, 10]	[10, 10]	[2, 4]	[2, 4]	[4.5, 6]	[2, 4]
ideal	[10, 10]	[10, 10]	[10, 10]	[10, 10]	[10, 10]	[10, 10]	[10, 10]
worst	[0, 0]	[0, 0]	[0, 0]	[0, 0]	[0, 0]	[0, 0]	[0, 0]

The fuzzy component of the extended multi criteria methodology can then be applied using interval arithmetic. A parameter value, *p*, of 1 is used to reflect equal compensation among the criteria. Also, no adjustments are applied in this example and equal criteria weights are used for model validation purposes. Thus, the final interval pairs are presented below, followed by the fuzzy distance metrics ($L_{j,y}$), which result from summing the in corresponding intervals across the rows:

	F1	F2	F3	F4	F5	F6	F7
SP1	[0.4, 0.55]	[0.6, 0.8]	[0.4, 0.55]	[0.6, 0.8]	[0.3, 0.3]	[0.9, 0.9]	[0.6, 0.8]
SP2	[0,0.1]	[0,0.1]	[0.6, 0.8]	[0.3, 0.3]	[0.5, 0.5]	[0.5, 0.5]	[0.6, 0.8]
SP3	[0, 0]	[0.6, 0.8]	[0.6, 0.8]	[0.9, 0.9]	[0.4, 0.55]	[0.3, 0.3]	[0.5, 0.5]
SP4	[0.9, 0.9]	[0.6, 0.8]	[0.4, 0.55]	[0.6, 0.8]	[0.5, 0.5]	[0.6, 0.8]	[0.6, 0.8]
SP5	[0.6, 0.8]	[0, 0]	[0, 0]	[0.6, 0.8]	[0.6, 0.8]	[0.4, 0.55]	[0.6, 0.8]

L1,y	[3.8, 4.7]
L2,y	[2.5, 3.1]
L3,y	[3.3, 3.9]
L4,y	[4.2, 5.2]
L5,y	[2.8, 3.8]

Defuzzification converts the fuzzy distance metric into a crisp distance metric and the method used to achieve defuzzification in this research is the Center of Gravity (CoG) method, which finds the geometrical center of the output variable. The CoG method is described below:

Let [x1, x2] = fuzzy distance metric intervals

Then, the DETS Center of Gravity (CoG) of the distance metric is defined as:

CoG_a [x1, x2] = $[x1(\alpha_1) + x2(\alpha_2)]/(\alpha_1 + \alpha_2)$Hence, the fuzzy distance metric is deffuzzified as shown in below, resulting in the first set of crisp (non-fuzzy) distance metrics:

x	T1	T2	T3	M(T,x) = alpha		
3.8	1.5	3	4.5	0.4667		
2.5	1.5	3	4.5	0.6667		
3.3	1.5	3	4.5	0.8000		
4.2	4	5	6.5	0.2000	T = (T1, T2, T3)	
2.8	1.5	3	4.5	0.8667	M(T, x) = 0	for x < T1
4.7	4	5	6.5	0.7000	M(T, x) = (x-T1)(T2-T1)	for T1 <= x<=T2
3.1	1.5	3	4.5	0.9333	M(T, x) = (T3-x)(T3-T2)	for T2 <= x<=T3
3.9	1.5	3	4.5	0.4000	M(T, x) = 0	for x>T3
5.2	4	5	6.5	0.8667		
3.8	1.5	3	4.5	0.4667		

x1	alpha1	x2	alpha2
3.8	0.4667	4.7	0.7000
2.5	0.6667	3.1	0.9333
3.3	0.8000	3.9	0.4000
4.2	0.2000	5.2	0.8666
2.8	0.8667	3.8	0.4667

a	CoGa
1	4.3400
2	2.8500
3	3.5000
4	5.0125
5	3.1500

DETS Network Component Computations

The network data is fed into the DETS computation engine as is. In the absence of decision-maker specified ideal-case and worst-case values, default system values will be applied and as previously discussed, benchmark values or extreme-case values will be used as default system values. In the 5 service provider example, an ideal-case value of 60 seconds and worst-case value of 10,000 seconds are used. In this case, these values were arbitrarily applied for demonstration purposes and the resulting non-fuzzy compromise programming distance metric set is given below:

Response Time
2312
3212
1002
699
1865

Non-Fuzzy Compromise Programming Distance Metrics	
Lx,1	0.2266
Lx,2	0.3171
Lx,3	0.0948
Lx,4	0.0643
Lx,5	0.1816

DETS Distance Metric Integration & Results

At this point in the DETS framework, two distance metrics have been computed. Figure 5-16 depicts the graphical interpretation of the distance metrics obtained from the DETS computation.

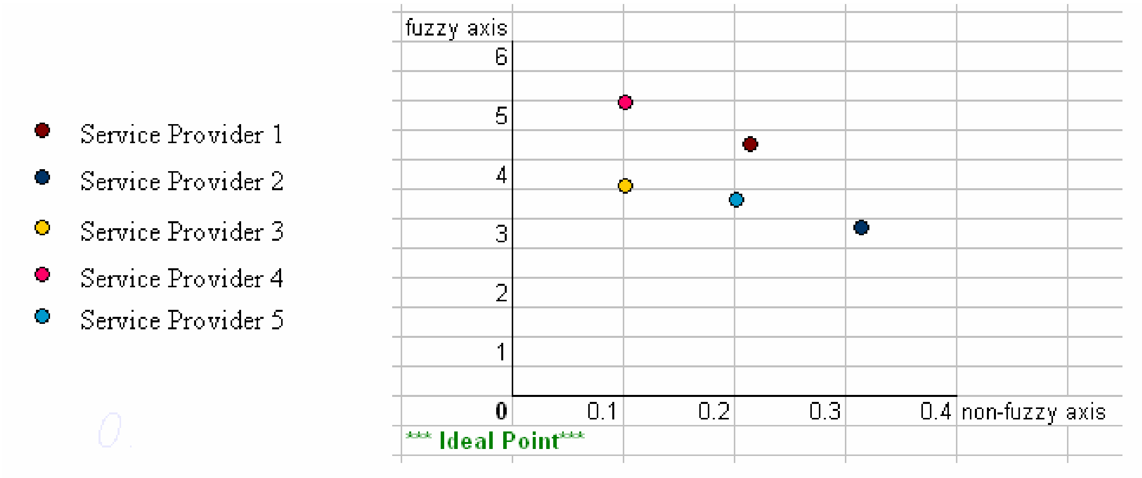


Figure 5-16 Distance Metric Interpretation

In this example, all the service providers appear to be a considerable distance from the ideal point. However, the choice of service provider still needs to be determined.

The graphical coordinates may not readily present an eyeball appreciation of the best service provider in the bunch, nevertheless the distance between the service provider coordinate pairs (x1, y1) and the ideal point (x2, y2) can be measured using the graphical distance formula:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Nevertheless, besides the direct graphical application of the metrics (x and y coordinates), other metric integration techniques were investigated. These included the *"addition"* and the *"averaging"* metric integration operations. In using an addition metric integration operation, the two sets distance metrics were added.

In the averaging metric operation, the average value of the distance metrics was used. Results of the three methods (direct graphical distance formula, addition and averaging) are shown in Table 5-17.

Table 5-17 DETS Distance Metrics Integration Methods

	Coordinates $L_{x,y}$	**Distance Formula** (Method 1) M1	**Addition** (Method 2) M2	**Average** (Method 3) M3	**DTI/RANK** (M1, M2, M3)
Service Provider 1	(4.3400, 0.2266)	4.3459	4.5666	2.2833	(4^{th}, 4^{th}, 4^{th})
Service Provider 2	**(2.8500, 0.3171)**	**2.8676**	**3.1671**	**1.5836**	**(1^{st}, 1^{st}, 1^{st})**
Service Provider 3	(3.5000, 0.0948)	3.5013	3.5948	1.7974	(3^{rd}, 3^{rd}, 3^{rd})
Service Provider 4	(5.0125, 0.0643)	5.0129	5.0768	2.5384	(5^{th}, 5^{th}, 5^{th})
Service Provider 5	(3.1500, 0.1816)	3.1552	3.3316	1.6658	(2^{nd}, 2^{nd}, 2^{nd})

From the table, it can be seen that all three DETS distance metric integration methods product the same results with Service Provider 2 being the "best-fit" or potentially the best choice for the decision-maker. However, in this example, all criteria had equal weights and no penalties or credits were applied. Looking at the preliminary data (before it was fed into the DET computation engine), it is not readily obvious that Service Provider 2 is the best choice with respect to other tradeoffs that could have been made or attempted by physically observing the data. Also, 'eyeball' analysis of the graphical representation of the distance metrics may not produce optimal results.

6.0 MODEL VALIDATION AND IMPLEMENTATION

6.1 MODEL VALIDATION AND IMPLEMENTATION

The DETS model was tested and validated using the trust for service evaluation case studies described in the previous chapter and others introduced in this chapter. The main goal of the validation procedure is to answer the question: Does the model accomplish the previously stated research objectives of providing a platform for evaluating service provider trustworthiness by making use of the Internet in e-Design? Is a pragmatic measure of trust provided for the decision maker through which decision-making can be made especially in the absence of any other information?

Below, the preliminary data (before it was fed into the DET computation engine) is analyzed with respect to the final results as shown below. The two distance metric sets are also presented. The preliminary data:

	F1	F2	F3	F4	F5	F6	F7	Service Response Time (Seconds)
SP1	6	3	6	4	7	1	4	2312
SP2	9	9	3	7	5	5	3	3212
SP3	10	2	3	1	6	7	5	1002
SP4	1	2	6	2	5	3	2	699
SP5	3	10	10	3	2	6	4	1865

The results:

	Coordinates $L_{x,y}$	Distance Formula (Method 1) M1	Addition (Method 2) M2	Average (Method 3) M3	DTI/RANK (M1, M2, M3)
Service Provider 1	(4.3400, 0.2266)	4.3459	4.5666	2.2833	(4th, 4th, 4th)
Service Provider 2	**(2.8500, 0.3171)**	**2.8676**	**3.1671**	**1.5836**	**(1st, 1st, 1st)**
Service Provider 3	(3.5000, 0.0948)	3.5013	3.5948	1.7974	(3rd, 3rd, 3rd)
Service Provider 4	(5.0125, 0.0643)	5.0129	5.0768	2.5384	(5th, 5th, 5th)
Service Provider 5	(3.1500, 0.1816)	3.1552	3.3316	1.6658	(2nd, 2nd, 2nd)

The distance metrics:

Non-Fuzzy Compromise Programming Distance Metrics

Lx,1	0.2266
Lx,2	0.3171
Lx,3	0.0948
Lx,4	0.0643
Lx,5	0.1816

Fuzzy Component Metric

a	CoGa
1	4.3400
2	2.8500
3	3.5000
4	5.0125
5	3.1500

From the preliminary data, it is not readily apparent that Service Provider 2 is the optimal choice based on the specified criteria. This is particularly true since Service Provider 2 also has the worst network data available (3212 seconds). If the decision maker in the demonstrated example is only interested in the network criteria of the potential service providers, then Service Provider 4 with a distance metric of 0.0643 would be the optimal choice. This is validated by the corresponding preliminary data entry of 699 seconds, which is the lowest response time available in the group of service providers.

However, if only the non-network data is of interest, then Service Provider 2 with fuzzy component distance metric 2.8500 is the best choice. Even though this corresponds to the combined overall result, it does not clearly validate the method. Thus, another case study will be used to validate the fuzzy component. Using 2 service providers (Q and Z) with non-network criteria values that can be readily "eye-balled" and decided upon:

	F1	F2	F3	F4	F5	F6	F7
Service Provider Q	10	9	9	10	9	9	10
Service Provider Z	0	1	1	0	2	3	2

From direct observation, Service Provider Q should definitely be chosen over Service Provider Z because Service Provider Q has more consistent *high* values. Computing the DTI via the DETS model produces the following distance metrics (CoG):

x	T1	T2	T3	M(T,x) = alpha
0.4	0	1	2	0.4000
5.7	4	5	6.5	0.5333
0.4	0	1	2	0.4000
6.1	6	7	8.5	0.1000

Fuzzy Distance Metrics	
L1,y	[1.4, 0.4]
L2,y	[5.7, 6.1]

x1	alpha1	x2	alpha 2	CoG
0.4	0.4	0.4	0.4	0.000
5.7	0.5333	6.1	0.1	0.127

From the results, it can be seen that Service Provider Z has a distance metric of 0.127. On the other hand, Service Provider Q has a distance metric of 0.000, which implies it is actually within the ideal region. Hence, Service Provider Q is the trustworthiest option.

Thus, the model is validated and verified. The inclusion of adjustments help in the application of some measure of control within the system. It ensures that there is consistency in the non-network component of the framework. It also provides certain checks and balances in the form of penalties and credits. The entire framework is flexible in its decision-making by allowing the decision maker highlight different components of the model as desired.

For implementation, a simulated trust evaluation environment is used. Simulation is an excellent and flexible tool to model different types of environments. Simulation also provides a platform for additional testing of a model [121]. It shows that the developed protocol can be implemented and it depicts the behaviour of the system.

Service providers exist within the system and event-driven occurrences simulate a change in provider capabilities or information. The invocation of such data should preempt certain changes within the trust framework. A properly designed simulation model captures and reflects framework capabilities. A graphical user interface presents a platform for the Request for Trust Evaluation process as shown in Table 6-1.

Trust data (and all sensitive information) is transferred within the framework in a secure manner. This is the underlying assumption of this research – a computationally secure e-Design infrastructure, in which this work provides a complementary tool for assessing service providers based on the concept of trust for service. The framework allows clients determine the trustworthiness of service providers and their resources by optimizing certain criteria and applying necessary tradeoff to approach some ideal point. The framework also allows for the establishment and propagation of trust data throughout the network at a sufficient rate to allow timely identification of malicious resources, thereby reducing the potential damage caused by their introduction. The adjustments help in provide adequate safeguards against the generation of false reputations and against the deletion of, or tampering with trust data.

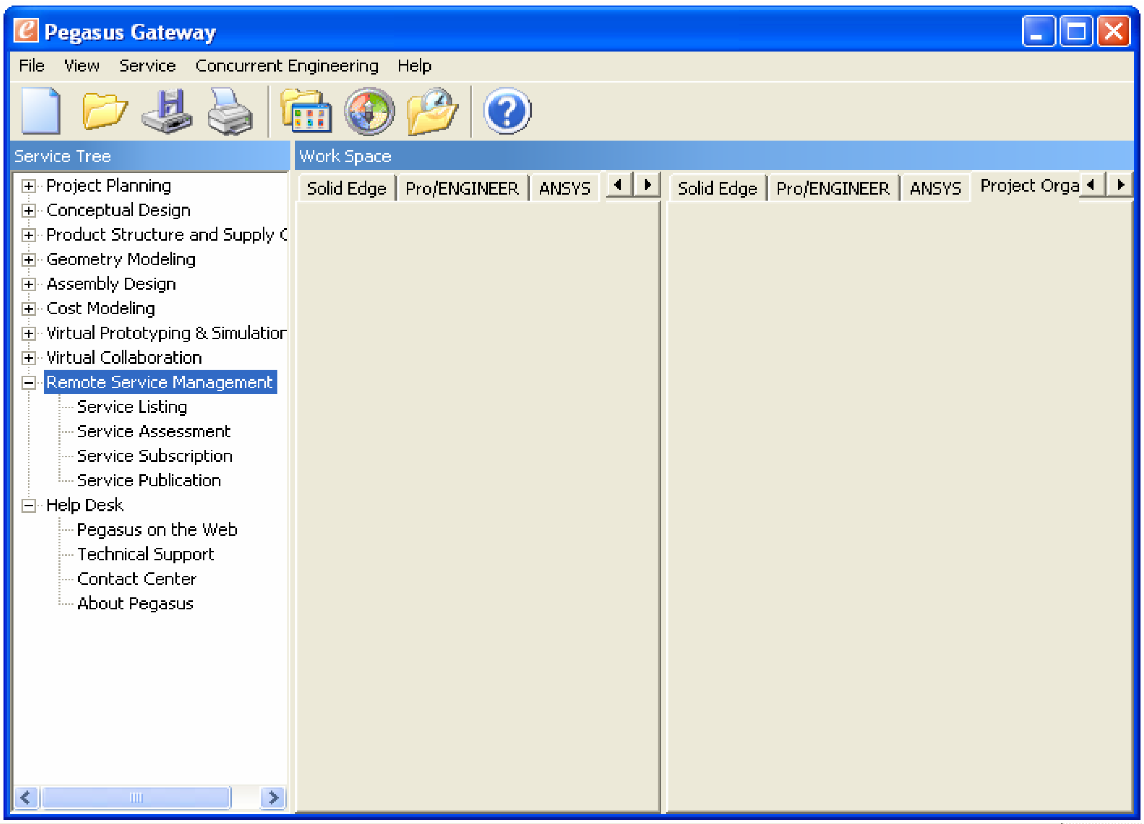


Table 6-1 Graphical User Interface

To test the pragmatic, everyday application or usability of the framework, a small survey was conducted with sample data, in which respondents were asked to (as best as they could) select their most trustworthy service provider (out of 2 alternatives: Service Provider Q and Service Provider Z). The cumulative results of the survey were compared to model output.

Also, the Analytic Hierarchy Process (AHP) was also used to test the model and validate the results (for the 'five service provider' case study). Sensitivity analysis was also used to investigate the robustness of the framework. That is, how do little or large changes in data values affect the results? As other variables are held constant, small and large variation are made to one or more input at a time and the results are analysed. This tests the proper functioning of the model.

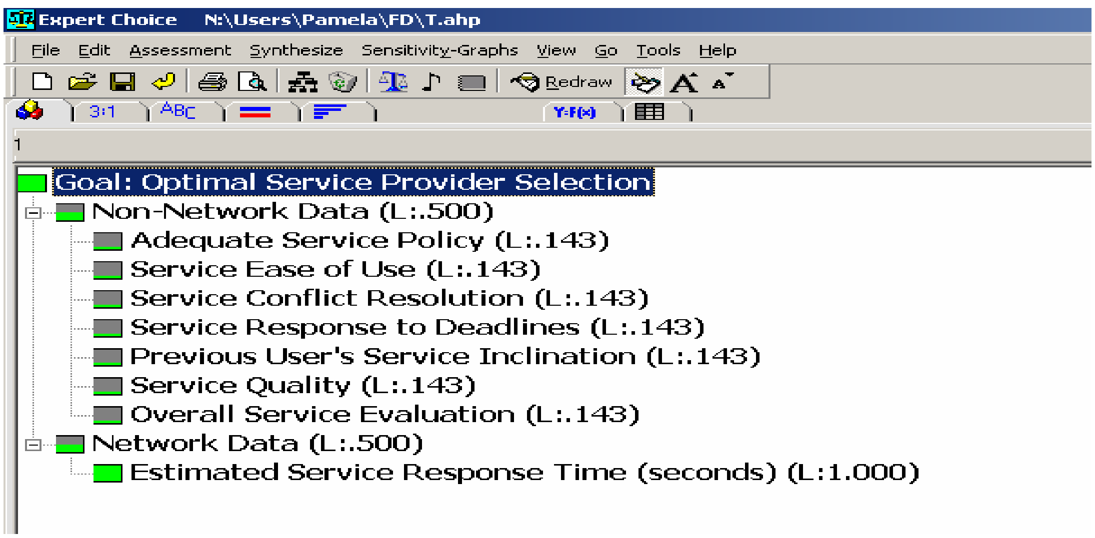


Table 6-2 AHP snapshot of model formation

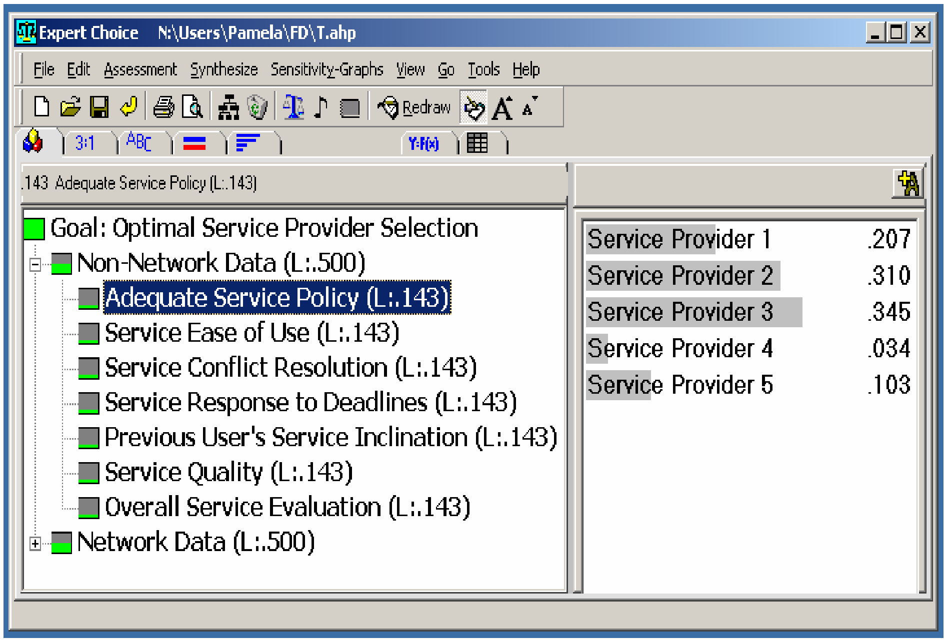


Table 6-3 AHP Highlight of Adequate Service Policy Criteria

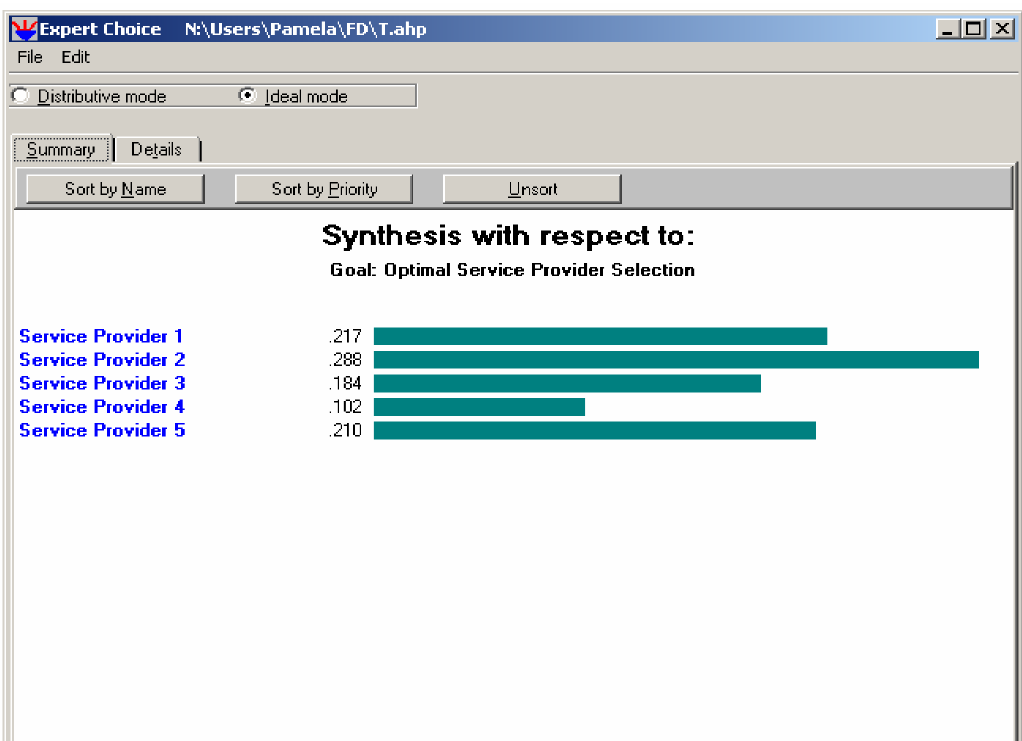


Table 6-4 AHP synthesis with respect to goal (without adjustment)

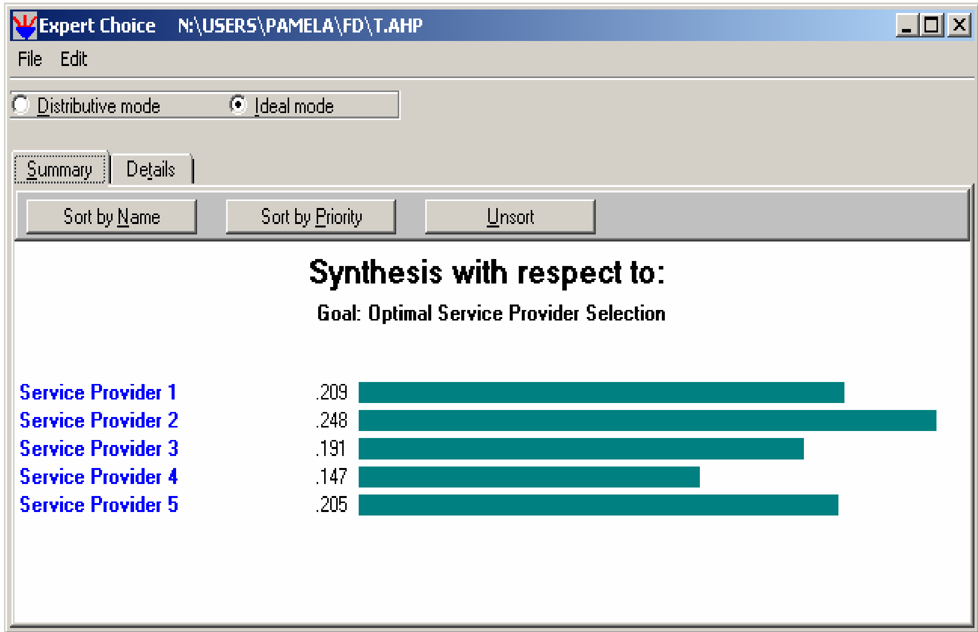


Table 6-5 AHP synthesis with respect to goal (with adjustment)

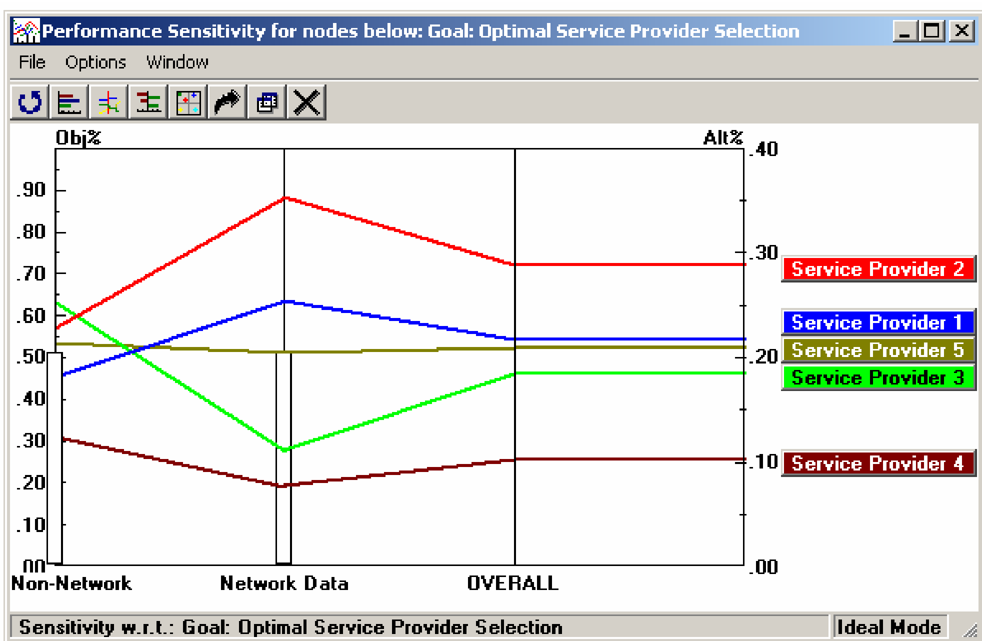


Table 6-6 AHP Performance Sensitivity Analysis

An Internet-based implementation of the Design Environment Trust Service framework is also being developed. This implementation of the model provides an accessible and downloadable graphics user interface for service provider and service trustworthiness assessment. Table 6-7 depicts the login front-end.

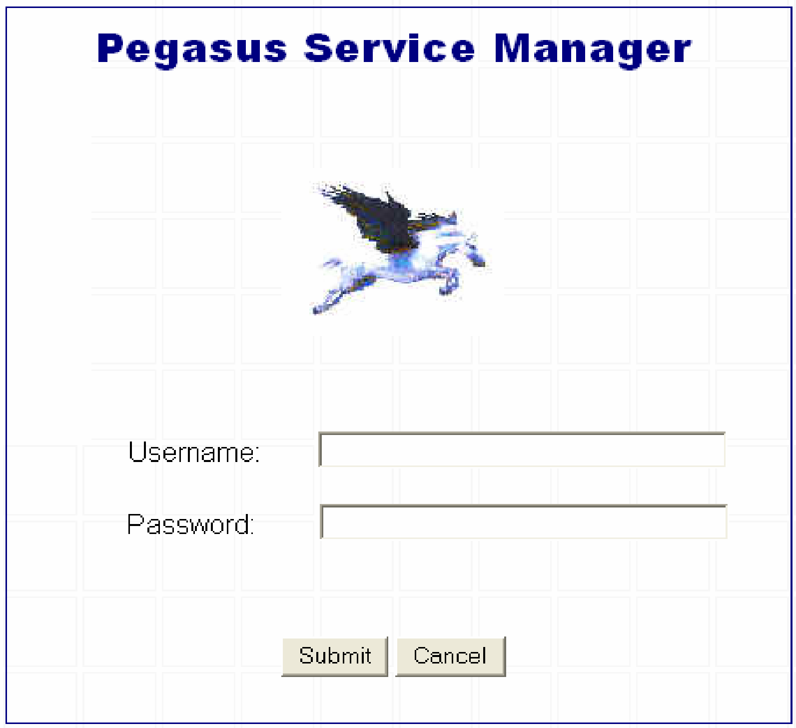


Table 6-7 Web-Based Graphical User Interface Front End

In the Pegasus Service Manager Demo 1.1, services are registered, can be viewed and evaluated. Table 6-8 to Table 6-10 depicts snapshots of the implementation environment.

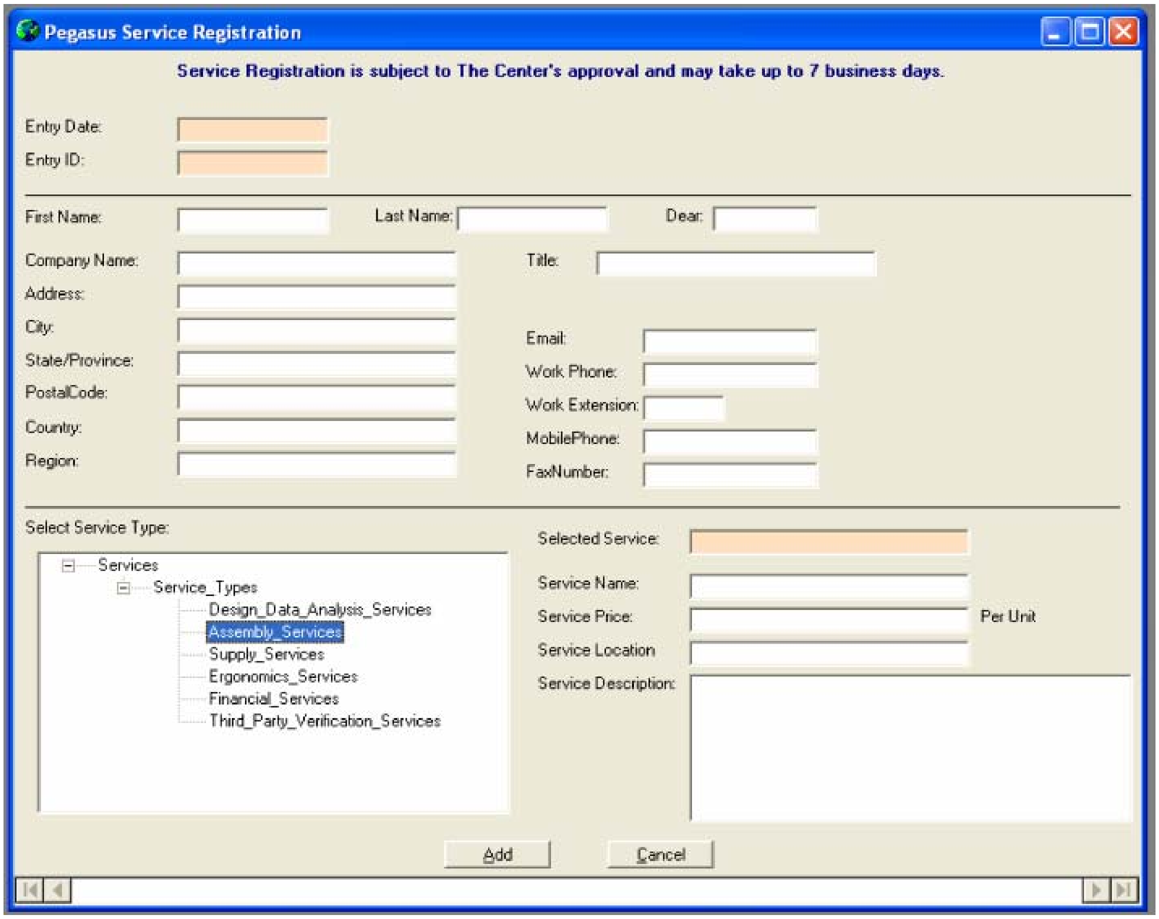


Table 6-8 Service Registration

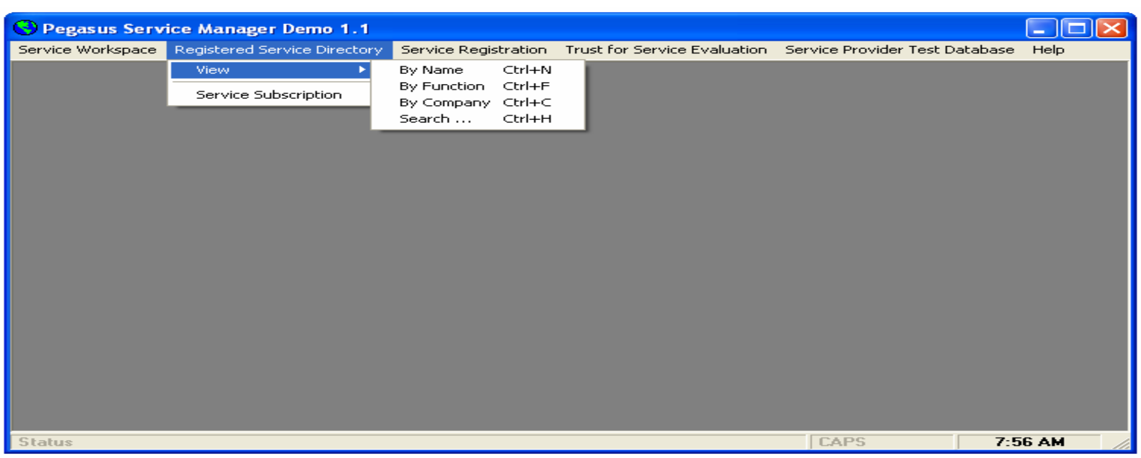


Table 6-9 Registered Service Directory View

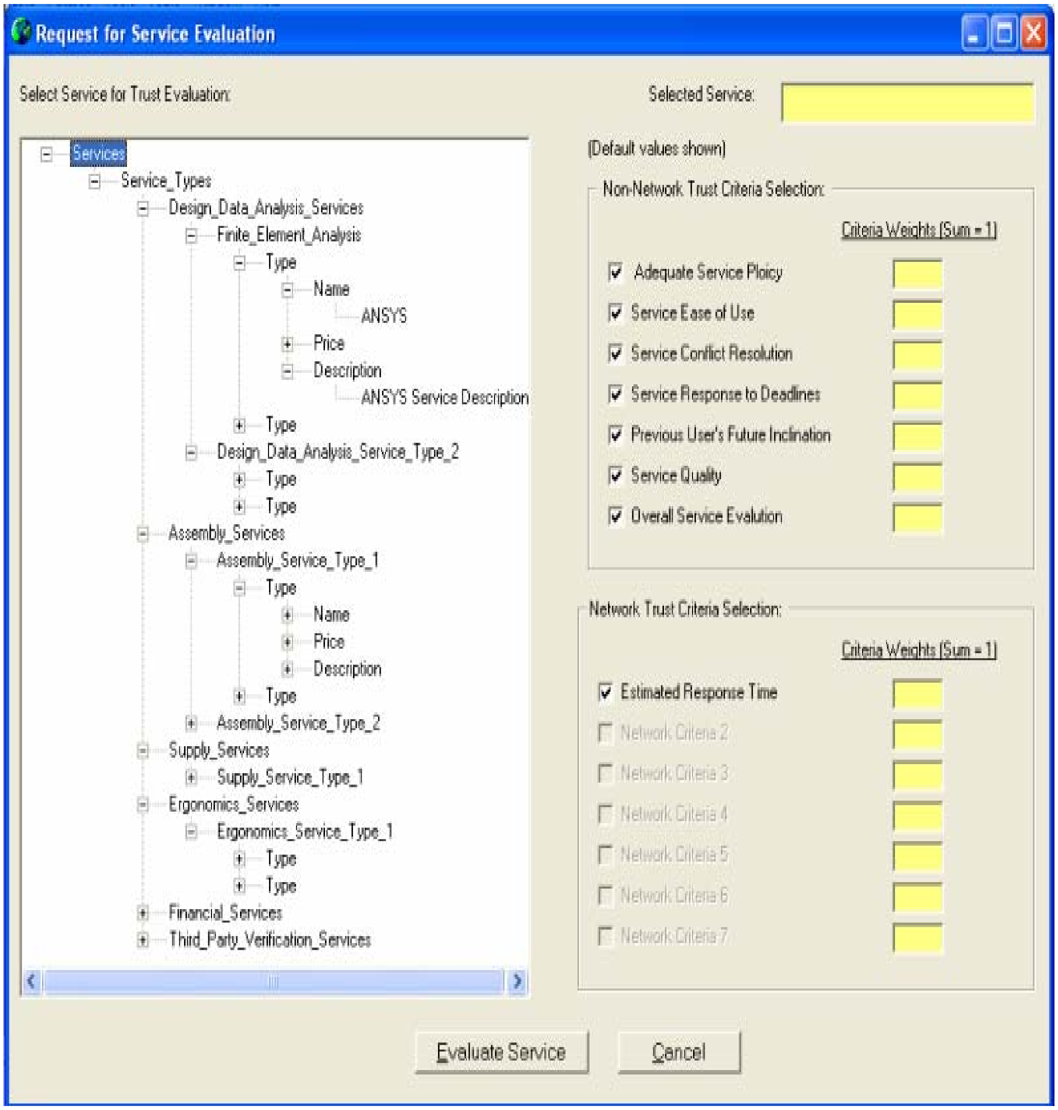


Table 6-10 Request for Service Evaluation

7.0 CONCLUSIONS

Collaborative product development is an answer to stricter market demands [122]. However, to get the most out of collaboration in eDesign, partner and service trustworthiness is essential. In this dissertation trust for service provision in distributed and collaborative product development was researched. Companies have found *distrust* of collaborative partners to be the most intractable obstacle to collaborative commerce, especially in intellectual property environments, which handle propriety data on a constant basis.

Also, trust is important to a firm's e-Business strategy [123] and in current Internet-enabled product development environments, the dynamic assessment and/or reassessment of collaborative partner service provision are either inadequate or totally non-existent. It is necessary to have a means of estimating trustworthiness especially in situations involving contradicting information [124]. Overcoming trust issues is a top priority for both business-to-consumer and business-to-business e-commerce [125].

The significant issues investigated in this research also include:

- The current dominance of Service-Oriented Architectures (SOA)
- The benefits of the accessibility of trustworthy distributed services
- The importance of the supply chain and other service providers in e-Design environments
- The absence of existing formalized trust building/maintenance processes and the need to improve current remote service selection methods

- Internet-enabled, collaborative and distributed product development may typically involve a lack of similarity, mutual organizational security and familiarity
- The fundamental relationship between trust, human interaction and cooperation

According to Stewart [126], if there is (a) ease of use by non-experts and (b) transparency of the logic of the method to the decision maker and (c) freedom from ambiguity regarding the inputs required from the decision maker, then the applied decision analysis method is “operationally useful”. This is what the methodology described in this documentation aims at.

7.1 SYSTEM FRAMEWORK

The main contribution of this research includes the provision of a working definition of trust in e-Design, the identification of factors that contribute to a general assessment of trust for service, the design and development of a design environment trust for service framework to estimate the trustworthiness of service providers in a distributed and collaborative product development environments and the use of a different approach in trust research using subjective user information and objective network data.

Benefits of a trust for service infrastructure in e-Design include better productivity, quality performance, seamless service provision boundaries, unlimited geographical issues, increased competitiveness and price regulation among service providers.

The primary objectives of this research were stated as follows:

i) To investigate and analyze trust for service issues with respect to the impact of the Internet on corporate, distributed, enterprise-wide e-Business networks

iv) Identification of the critical trust issues concerning honestly, openness, reliability, competence and benevolence and investigate suitable means of data collection and the relationship of the collected data to trust through studies and statistical analysis and

v) Design and development of a suitable framework and trust-support infrastructure along with complementary frameworks for building vital trust architectures for services delivered in electronic- (web-based) product design and realization

A suitable trust system framework has been research to allow for trustworthy service provision with the e-Design environment. The Design Environment Trust Service (DETS) framework uses a user-centered approach to allocate a trust measure to collaborative service providers within the design environment. Such trust information can go a long way in mitigating information asymmetry regarding trustworthy service provision.

7.2 DATA COLLECTION AND ANALYSIS

The selection of a service provider in e-Design environments is a non-trivial process. It depends on a variety of factors including data. The common thread that holds most of these factors together is trust, which has been defined as the driver of electronic business. Choice of the right service provider can be gauged based on public reputation or asking for recommendations and these are both valid approaches [127].

Various methods were used to collect information regarding non-network data. These included *focus groups, surveys and questionnaires.* Surveys/questionnaires were also used to collect data and provide a lot of advantages such as a variety of questions and anonymous answers. By using surveys or questionnaires, respondents are given enough time to respond to the questions. Also, information can be collected on the same questions from all respondents. However, the surveys/questionnaires required some time to develop in order to ensure good questions. Four major survey sessions were conducted.

Respondents were randomly selected and each is assumed to be independent of the others based on personal and subjective conceptions of trust. Another reason for the independence assumption is that it is unlikely that the respondents all participate in totally identical service scenarios or respond in totally identical ways to service situations.

As a result of the independent random factors that act in an additive manner to create variability among the collected data, the data analysis assumes that the population follows a Gaussian (also called the Normal distribution) distribution as mentioned previously, so that inferences can be made about the mean and other properties of the population.

Also, based on the data collection and responses from respondents, a working definition of trust for service in e-Design was presented and based on this definition, the trust for service process was formalized as a model using network and non-network data to achieve a dynamic estimate of service provider trustworthiness at a given point in time. A Combined Fuzzy & Non-Fuzzy Compromise Programming with Trust Penalty and Credit Adjustment methodology was used as an extended multi criteria decision-making (MCDM) technique to assist in trust building and management.

7.3 TRUST INDEX COMPUTATION

The complementary trust tool developed in this research will promote product design and development collaboration and improve the entire life cycle of a product from conceptualization to product realization and manufacture. A Dynamic Trust Index (DTI) is used to qualify each service provider after trust evaluation. In obtaining the DTI, the DETS framework uses a Combined Fuzzy and Non-Fuzzy Compromise Programming with Trust Penalty and Credit Adjustment multi criteria optimization methodology.

Providing an estimate of trust for service provision in collaborative product design is critical in product design. Thus, this research investigates the issue of service provider trustworthiness and Table 7-1 provides a snapshot of the synopsis of the method used in this research.

Table 7-1 Design Environment Trust Service Methodology Synopsis

Research Steps	Activities	Main Tool(s)	Contribution(s)
Representation of *Trust for Service* Evaluation Problem in e-Design Environments	→ Problem definition → Conceptual model design → Data Collection	- Literature review - Focus groups, interviews, surveys, reports, observations	* Formal working definition of *Trust for Service* in e-Design and focus on the problem and formal identification of user-specified criteria that contribute to an assessment to trust * New application/approach for Multi Criteria Decision Making (MCDM) methodology
Detailed model design and development	→ Data analysis → Model development	- Statistic data analysis - Analytical Hierarchy Process (AHP)	* Development of the *Design Environment Trust for Service (DETS)* framework model
Penalty and credit adjustment integration	→ Red flag penalty adjustment → Other penalty adjustment e.g. survival rate of malicious agents and trust recovery factors	1. Penalty modules 2. Fuzzy theory, statistics, probabilities, rule sets 3. Data analysis and inference	* Improvement of the service provision selection decision by accounting for penalties and credits (negative penalties)
Dynamic (Design) Trust Index (DTI) computation	→ Account for (and separating) non-network data and fuzzifying accordingly → Account for (and separating) network data → Perform criteria tradeoffs with any adjustments and defuzzify (where necessary) → Obtain distance metrics and the DTIs	1.Fuzzy Theory/Logic 2.Penalty (credit) adjustment factor 3.Combined Fuzzy/Non-Fuzzy Compromise Programming with Penalty Adjustment	* An extension of/new approach to the Compromise Programming method allowing for reduced input ambiguity/vagueness and balance in the tradeoff decisions * This method does not promote the fuzzification of objective data * A complementary tool for e-Design decision making

7.4 RESEARCH EXTENSIONS

Research extensions for this work include further individual investigation on the trust criteria discussed previously and the inclusion of other potential criteria. Also the issue of *distrust* criteria is an important concept for future research as supported by McKnight et al [128].

Extending the framework described in this documentation should allow clients (and eventually service providers) determine the trustworthiness of service providers (and clients) by optimizing specified criteria and applying appropriate tradeoffs to approach an ideal or target point. With further investigation, the framework will allow for the establishment and propagation of trust data throughout the network at a sufficient rate to allow timely identification of malicious resources, thereby reducing the potential damage caused by their introduction.

Future research considerations also include considering data overload and management scenarios with respect to client, service manager and service provider storage space in terms of repository data. Intellectual property methods [129], policy language research and framework applications to other areas are also viable research routes.

APPENDIX A

DATA STUDY

Pilot Survey Setup:

Trust for Service Feedback Form Research: Sample Questionnaire & A Survey
Author: P. Ajoku

Scenario: Consider an online marketplace in which services are made available for hire or purchase from legitimately registered but unknown vendors. What kind of feedback data would you consider necessary and sufficient to enable you make an appropriate decision regarding trust for the service in question if you had not previously used this service and but may use it sometime in the future. Please look at the sample questionnaire and then answer the short set of questions that follow:

The Questionnaire:

1. Overall Service Satisfaction:
Options: {Very Satisfactory, Satisfactory, Neutral, Unsatisfactory, Very Unsatisfactory}

2. Service Ease of Use:
Options: {Very Easy, Easy, Neutral, Difficult, Very Difficult}

3. Conflict/Resolution:
Options: {No Conflict, Conflict/Resolved, Conflict/Unresolved}

4. Response to Deadlines:
Options: {Prompt Service, Ok, On Time, Delayed, Late}

5. Would you recommend this service?
Options: {Yes, No, Not Sure}

6. Would you use this service again?
Options: {Yes, No, I Don't Know}

Dependent Variable	Trust						
Independent Variables	Simple rating	Overall Service Satisfaction	Ease of Use	Conflict-Resolution	Response	Recommendation	Future Use
Options	Positive	Very Satisfactory	Very Easy	No Conflict	Prompt Service	Yes	Yes
	Neutral	Satisfactory	Easy	Conflict Resolved	Ok	No	No
	Negative	Neutral	Neutral	Conflict Unresolved	On Time	Not sure	Not sure
		Unsatisfactory	Difficult		Delayed		
		Very Unsatisfactory	Very Difficult		Late		

FACTOR	CRITICAL	NEUTRAL	NOT CRITICAL
Example: Adequate Service Policy	☒ 6	☐ ____	☐ ____
Adequate Service Policy	☐ ____	☐ ____	☐ ____
Service Ease of Use	☐ ____	☐ ____	☐ ____
Service Conflict Resolution	☐ ____	☐ ____	☐ ____
Service Response to Deadlines	☐ ____	☐ ____	☐ ____
Previous User's Inclination to Use Service Again	☐ ____	☐ ____	☐ ____
Service Quality	☐ ____	☐ ____	☐ ____
Overall Service Evaluation	☐ ____	☐ ____	☐ ____

TRUST RESEARCH SURVEY

Author: NSF Center for e-Design, Department of Industrial Engineering, University of Pittsburgh

Dear Respondent,

This survey is for a research study on "*Trust for Services* in Internet-Enabled Service-Oriented Environments". Your input is greatly appreciated. *Trust for Service* is defined, in the context of this research, as a quantifiable degree of belief expressed by one party that another party will deliver a specified service in a manner that is standard or previously agreed upon for a specified time period. We are interested in how the 7 factors listed below contribute to your perception of trust for online service provider decision-making.

<u>Factor Definitions (For Reference Purposes):</u>

Adequate Service Policy: **Presence of a suitable set of guidelines regarding the online service**
Service Ease of Use: **Usability of the online service**
Service Conflict Resolution: **Information on the status of any service disputes**
Service Response to Deadlines: **Speed and manner in which service provider responds to any previously agreed upon or customer specified deadlines**
Previous User's Inclination to use Service Again: **Previous user's attitude towards using the same service again**
Service Quality: **Distinguishing characteristics of the service**
Overall Service Evaluation: **Summary of the service based on the factors mentioned above**

<u>Survey Context or Scenario:</u>

You are in an environment with immense intellectual property and you need to select an online (Internet-based) service provider you have never used in the past for some service, which has some or all of its delivery via the Internet. Please answer the questions that follow. Thank you very much for your contribution to this research!

(1) SELECT ONE**:** **I am a Student** **Other (please specify) e.g. CEO, Engineer etc** ____

(2) MAIN SURVEY QUESTIONS: **In your choosing an online service provider, is:**

***** **An** Adequate Service Policy **more important than** Service Ease of Use**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** **An** Adequate Service Policy **more important than** Service Conflict Resolution**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** **An** Adequate Service Policy **more important than** Service Response to Deadlines**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** **An** Adequate Service Policy **more important than** Previous User's Inclination**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** **An** Adequate Service Policy **more important than** Service Quality**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** **An** Adequate Service Policy **more important than** Overall Service Evaluation**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** Service Ease of Use **more important than** Service Conflict Resolution**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** Service Ease of Use **more important than** Service Response to Deadlines**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** Service Ease of Use **more important than** Previous User's Inclination**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** Service Ease of Use **more important than** Service Quality**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** Service Ease of Use **more important than** Overall Service Evaluation**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** Service Conflict Resolution **more important than** Service Response to Deadlines**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** Service Conflict Resolution **more important than** Previous User's Inclination**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________
***** Service Conflict Resolution **more important than** Service Quality**?** **YES** _______ **No** _________ **Maybe** ________ **Unsure** ________

***** Service Conflict Resolution **more important than** Overall Service Evaluation**?**	**YES** _______	**No** _________	**Maybe** ________	**Unsure** ________
***** Service Response to Deadlines **more important than** Previous User's Inclination**?**	**YES** _______	**No** _________	**Maybe** ________	**Unsure** ________
***** Service Response to Deadlines **more important than** Service Quality**?**	**YES** _______	**No** _________	**Maybe** ________	**Unsure** ________
***** Service Response to Deadlines **more important than** Overall Service Evaluation**?**	**YES** _______	**No** _________	**Maybe** ________	**Unsure** ________
***** Previous User's Inclination **more important than** Service Quality**?**	**YES** _______	**No** _________	**Maybe** ________	**Unsure** ________
***** Previous User's Inclination **more important than** Overall Service Evaluation**?**	**YES** _______	**No** _________	**Maybe** ________	**Unsure** ________
***** Service Quality **more important than** Overall Service Evaluation**?**	**YES** _______	**No** _________	**Maybe** ________	**Unsure** ________

(3) USING THE CONDITIONS GIVEN IN THE SURVEY CONTEXT, WHAT MINIMUM COMBINATION OF THE FACTORS BELOW WILL GIVE YOU A PERCEPTION OF TRUST FOR THE SERVICE?

The different levels represent the summary of network information regarding the service in question. Please place a check mark for the minimum level of each factor that will result in a perception of trust for the service provider:

Presence of an Adequate Policy/Contract: 3 – Yes _____________
2 – Maybe _____________
1 - No _____________

Average Service Ease of Use Report: 3 – Easy _____________
2 – Neutral _____________
1 – Difficult _____________

Average Service Conflict Resolution Report: 3– No Conflict ____________
2– Conflict/Resolved ____________
1– Conflict/Unresolved ____________

Average Service Response to Deadlines Report: 3– Prompt _____________
2– OK _____________
1– Delayed _____________

Previous User's Inclination to Use Service Again: 3– Yes _____________
(Report Summary) 2– Not Sure _____________

1– No ____________

Average Service Quality Report:

3– Very Good ____________
2– Ok ____________
1– Poor ____________

Overall Service Summary Report

3- Positive ____________
2- Neutral ____________
1- Negative ____________

TRUST RESEARCH SURVEY

Author: P. Ajoku, NSF Center for e-Design, Department of Industrial Engineering, University of Pittsburgh

Dear Respondent,
This survey is for a research study on "*Trust for Services* in Internet-Based Service-Oriented Environments" being conducted by the NSF Center for e-Design at the University of Pittsburgh. Your input is very important, greatly appreciated and will be kept confidential. A summary of the results of this study will be available upon request. *Trust for Service* is defined, in the context of this research, as a quantifiable degree of belief expressed by a Party A that another Party B will deliver a specified service in a manner that is standard or previously agreed upon for a specified time period. For this survey, first (1)**: Please select the category to which you most likely belong e.g. Student, Engineer etc. (please select only one). We are interested in how the 7 factors defined below contribute to your perception of trust for online service provider decision-making. Secondly** (2)**: A matrix is provided with 7 trust factors presented in both the rows and columns. For each row and column intersection, please assign in the upper matrix triangle – denoted by** * **, a RANK NUMBER from 1-9 as explained by the RANK DEFINITION section below.**
Thirdly (3)**, please provide a ranking for the factors on an individual basis. Finally** (4)**, please answer a few questions for classification purposes.**

<u>Factor Definitions (For Reference Purposes):</u>
Adequate Service Policy: **Presence of a suitable set of guidelines regarding the online service**
Service Ease of Use: **Usability of the online service**
Service Conflict Resolution: **Information on the status of any service disputes**
Service Response to Deadlines: **Speed and manner in which service provider responds to any previously agreed upon or customer specified deadlines**
Previous User's Inclination to use Service Again: **Previous user's attitude towards using the same service again**
Service Quality: **Distinguishing characteristics of the service**
Overall Service Evaluation: **Summary of the service based on the factors mentioned above**

<u>RANK DEFINITIONS FROM 1 (LOWEST VALUE) TO 9 (HIGHEST VALUE)</u>

If YOUR ASSIGNED RANK = 1 then the ROW FACTOR **is absolutely less important than the** COLUMN FACTOR
If YOUR ASSIGNED RANK = 3 then the ROW FACTOR **is weakly less important than the** COLUMN FACTOR
If YOUR ASSIGNED RANK = 5 then the ROW FACTOR **is equally as important than the** COLUMN FACTOR
If YOUR ASSIGNED RANK =7 then the ROW FACTOR **is a weakly more important than the** COLUMN FACTOR
If YOUR ASSIGNED RANK = 9 then the ROW FACTOR **is absolutely more important than the** COLUMN FACTOR

Note: RANKS OF 2, 4, and 8 **may be used to signify values in between the ranks described above.**

(1) SELECT ONE: **I am a** ☐ **Student** ☐ **Faculty Member** ☐ **Industry Personnel (Please Give Title)** ______________ ☐ **Other (Please Specify)** ___________

(2) PLEASE ASSIGN RANKS (1 – 9) IN THE LIGHT SHADED AREAS OF THE MATRIX BELOW:

	Adequate Service Policy	Service Ease of Use	Service Conflict-Resolution	Service Response to Deadlines	F6 = Previous Users' Inclination to Use Service Again	F7 = Service Quality	Overall Service Evaluation
Adequate Service Policy	1	*	*	*	*	*	*
Service Ease of Use		1	*	*	*	*	*
Conflict-Resolution			1	*	*	*	*
Response to Deadlines				1	*	*	*
Previous Users' Inclination to Use Service Again					1	*	*
Service Quality						1	*
Overall Service Evaluation							1

(3) On a scale of 1 to 9, where 1 denotes the LOWEST VALUE and 9 denotes the HIGHEST VALUE; please classify the seven factors individually:

Example: **Adequate Service Policy is CRITICAL for** MY **selection of an online service provider with a scale value of 6. The value 6 denotes the strength of this choice.**

PLEASE CHOOSE ONLY ONE COLUMN PER ROW

FACTOR	CRITICAL	NEUTRAL	NOT CRITICAL
Example: Adequate Service Policy	☒ 6	☐ ___	☐ ___
Adequate Service Policy	☐ ___	☐ ___	☐ ___
Service Ease of Use	☐ ___	☐ ___	☐ ___
Service Conflict Resolution	☐ ___	☐ ___	☐ ___
Service Response to Deadlines	☐ ___	☐ ___	☐ ___
Previous User's Inclination to Use Service Again	☐ ___	☐ ___	☐ ___
Service Quality	☐ ___	☐ ___	☐ ___
Overall Service Evaluation	☐ ___	☐ ___	☐ ___

(4) A few optional questions (for classification purposes):

Sex: Female Male

Name of Organization ______________________________________ Years of Experience in Organization ______________

Average number of (any) online transactions made per month __________

T H A N K Y O U!!!

APPENDIX B

NETWORK DATA COLLECTION TOOLS

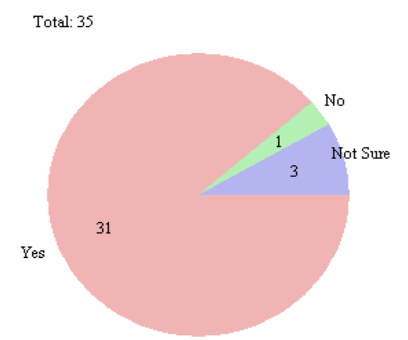
Name	Description	Source
Argus	Argus is a powerful tool for monitoring IP networks. It provides tools for sophisticated analysis of network activity that can be used to verify the enforcement of network security policies, network performance analysis and more.	Anonymous ftp at ftp.andrew.cmu.edu
Arpwatch	An ethernet monitor program that keeps tracks of ethernet/IP address pairings	Anonymous ftp at ftp.ee.lbl.gov
Courtney	It is a program that tries identifies the use of SATAN on a subnet. The program tcpdump will also be needed in order to run Courtney. See below for information above tcpdump	Anonymous ftp at ciac.llnl.gov; *Additional Info*: CIAC Notes 08
Dig	Dig is a network utility which queries Domain Name Servers similar to nslookup but it's more reflexible.	Anonymous ftp at venera.isi.edu
Drawbridge	Powerful bridging filter package.	Anonymous ftp at net.tamu.edu

APPENDIX C

DATA ANALYSIS

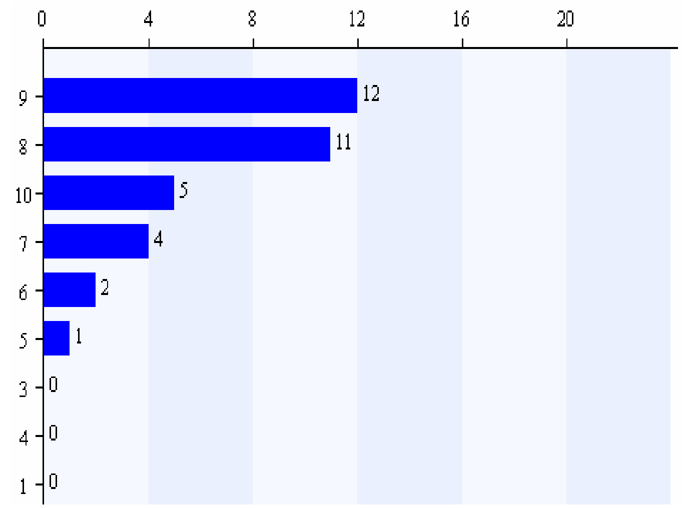
PILOT STUDY DATA RESULTS:

Question 1:
Did you understand all the questions in the questionnaire?



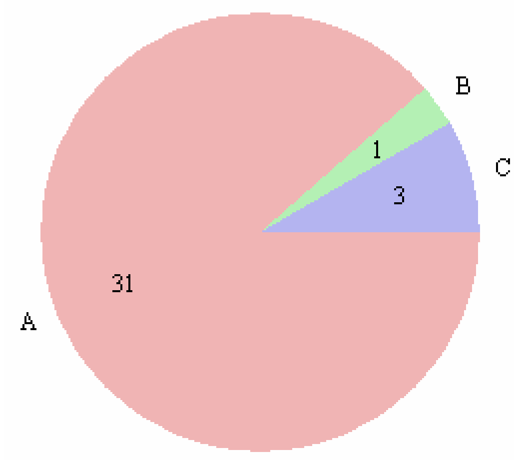
Question 2:

On a scale of 1 - 10 (where 10 means you will most likely and 1 means least likely), would you answer a short questionnaire like the one on the previous page if you were asked to do so after receiving service from a service provider?



Question 3:
If an independent sample of people provided you with answers to the questions in the questionnaire on the previous page, would you be able to make an informed decision on whether or not to hire the same service from the same service provider?

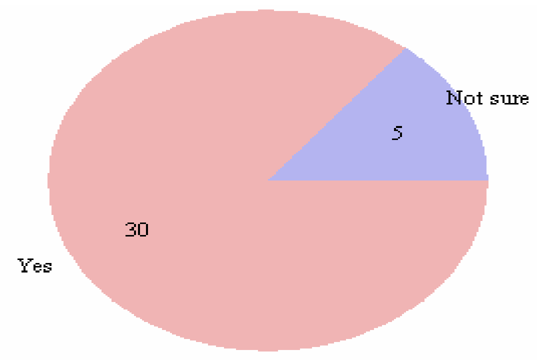
A- Yes, I can base my decision on feedback from the questionnaire on the previous page (31)
B- No, I cannot base my decision on feedback from the questionnaire on the previous page (1)
C- Maybe, I can base my decision on feedback from the questionnaire on the previous page (3)



Question 4:
If you answered "No" or "Maybe", how would you make an informed decision on whether or not to hire the same service from the same service provider?

Respondent # 15: “not sure at this time”
Respondent #26: “well, it’s a tricky thing – I don’t know”
Respondent #29: “Some crucial questions were not asked.
Money involved?”
Respondent #33: “Collect more info”

Question 5:
Given the current state of online commerce and services, do you feel feedback data would be helpful in making your decision?



Question 6:
How would you define user trust for online services?

Respondent #	Response
1	Knowledge based on facts
2	Confidence for business or any transaction with another party
3	A kind of belief – how do you measure belief?
4	A measure of confidence
5	Knowing that a party will fulfill a previously stated obligation
6	Dependability
7	Faith in another part's service
8	Trust is a belief than an individual or cooperation will do some agreed action

9	I trust you because I have a belief regarding some key points or issue
10	Evidence that the party can provide what I want
11	It depends on the context in which it is used
12	I depend on you with facts or hope
13	Difficult to define – a belief
14	Trust is the ability to determine if a party is reliable
15	Total reliance
16	Belief that another party will deliver something – an item, a service
17	Belief in good from another person
18	Trust means confidence and is subjective and dynamic
19	Trust is belief that a part will do as stated
20	Trust is confidence that something will be done
21	Trust is being able to say that the party will (be) ok or expected to be ok
22	Dependability
23	Dependability or confidence in goods delivered
24	No problems before, good history
25	Confidence in delivery of service
26	Safety, reliable
27	Difficult to explain
28	Impression, confidence
29	Gets better each day but not quite there!
30	Being able to rely on the seller
31	If an index is given or provided, it will help my decision to trust
32	Use of online services with the assurance

	that all information will be kept confident and none will be lost
33	How much the user feels happy and secure when he uses the online service
34	Know who I am dealing with and how my information is handled
35	Trust is confidence

Question 7:
Regarding the initial questionnaire, what other questions do you think will provide you with an acceptable level of trust for an online service if you were to receive feedback from someone who has just used the same service you plan to purchase?

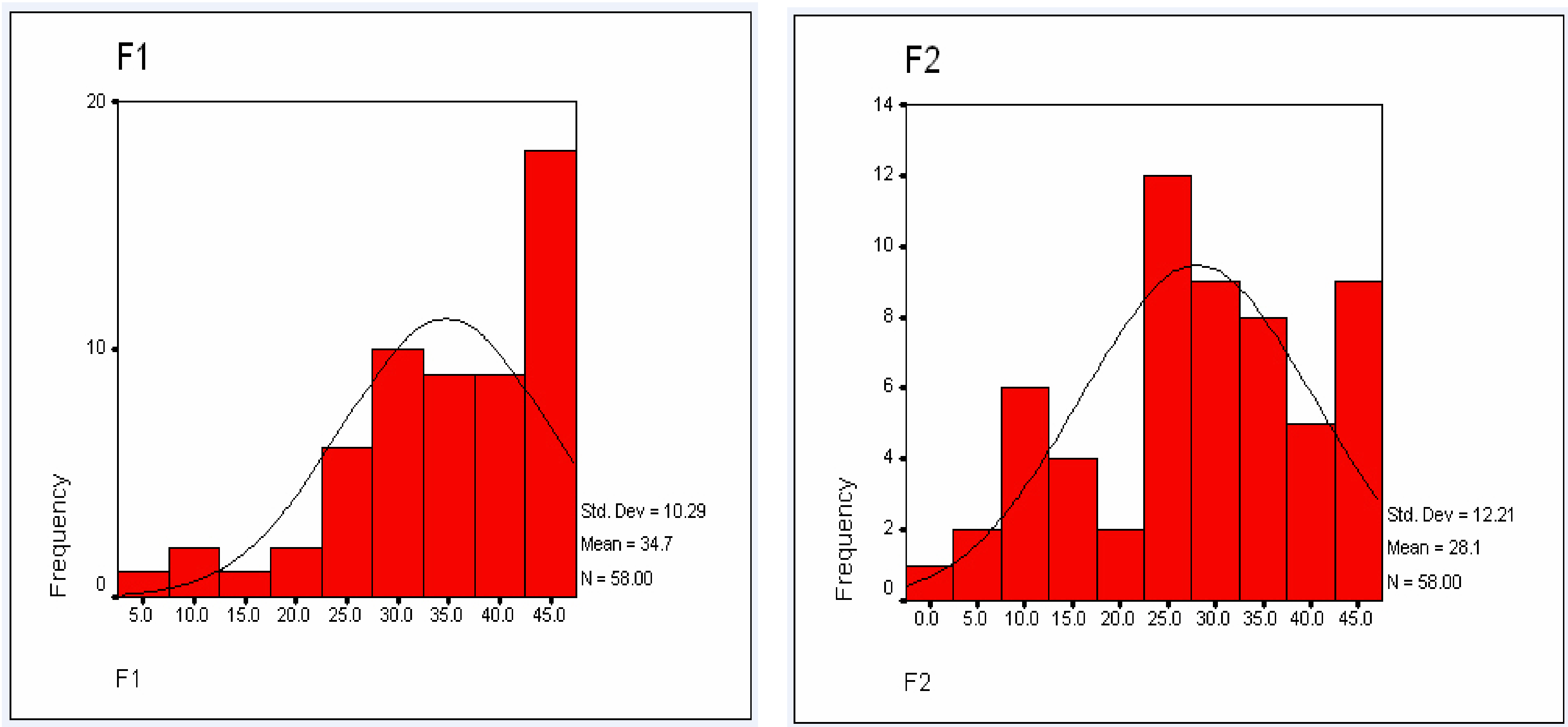
Respondent #	Response
1	None
2	Quality/recommendations
3	Not sure; Is overall satisfaction a redundant question
4	A rating of service quality
5	A simple positive/negative experience rating may do; long questionnaires may not get much attention
6	None
7	None
8	Ok
9	None comes to mind. Questions ok
10	None
11	The previous questions are ok; May not apply to all situations anyway
12	How long have you been in service
13	Too many questions make it difficult to interpret
14	Ok, I think

15	Is the service provider well known?
16	Can't think of any
17	I would not include the overall service rating since the other questions give detail regarding the transaction
18	No need for the option "Ok" and "On Time" regarding question 4
19	Nine
20	Would you recommend the service?
21	Nil
22	Questions ok.
23	Response to deadline question??? What if there is no deadline???
24	The questions are good
25	Okay I think
26	Is the person reliable
27	Not sure at this time
28	Is it possible to get some info on the people giving feedback
29	Type of service rendered, was money involved
30	Were there any other problems?
31	The conflict/resolution problem is somewhat unclear; The conflict notion is quite subjective
32	How useful was the service? How thorough was the service?
33	NA
34	What is the feedback of previous customers?
35	None

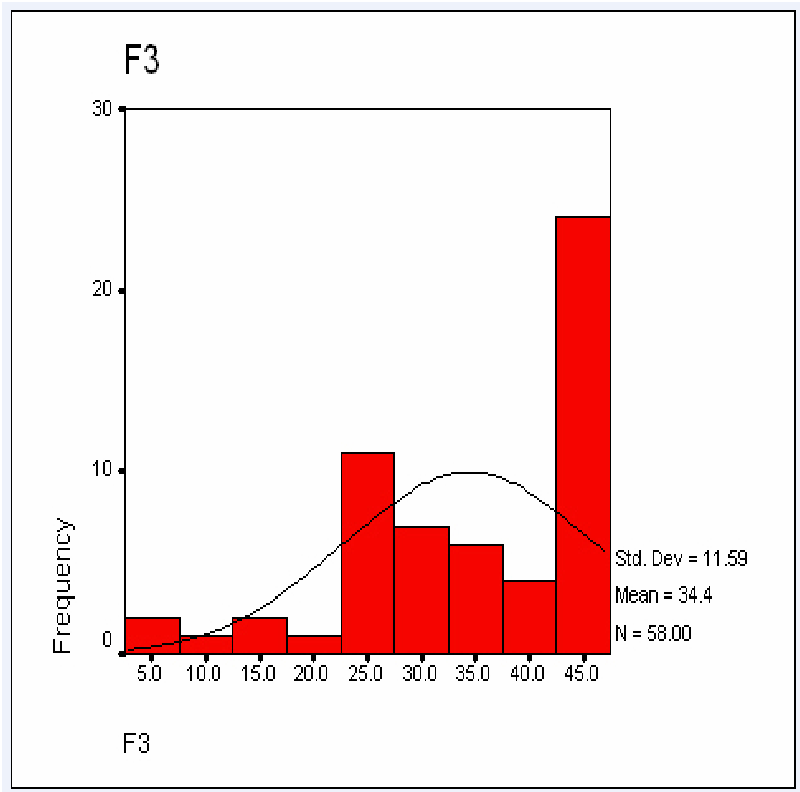
Other Data Survey Data Analysis:

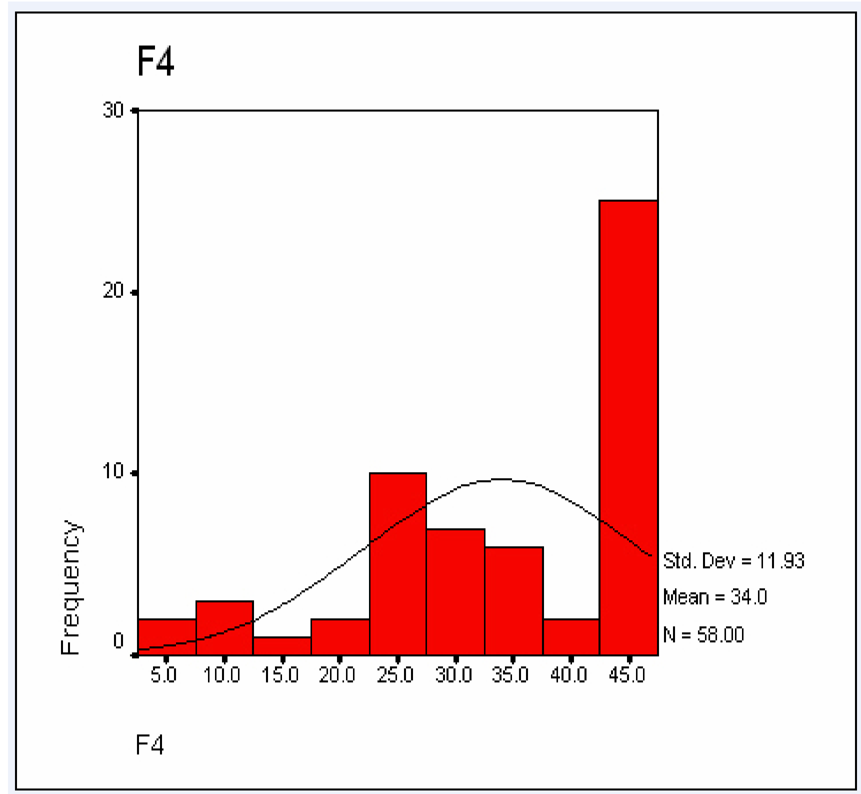
Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	F1 - F2	6.6552	11.82705	1.55297	3.5454	9.7649	4.285	57	.000
Pair 2	F1 - F3	.3103	10.05983	1.32092	-2.3348	2.9554	.235	57	.815
Pair 3	F1 - F4	.7414	10.46055	1.37354	-2.0091	3.4918	.540	57	.591
Pair 4	F1 - F5	9.3621	13.29912	1.74626	5.8652	12.8589	5.361	57	.000
Pair 5	F1 - F6	-4.7759	9.36407	1.22956	-7.2380	-2.3137	-3.884	57	.000
Pair 6	F1 - F7	-2.8103	10.52392	1.38186	-5.5775	-.0432	-2.034	57	.047
Pair 7	F2 - F3	-6.3448	11.34553	1.48974	-9.3280	-3.3617	-4.259	57	.000
Pair 8	F2 - F4	-5.9138	12.78470	1.67871	-9.2754	-2.5522	-3.523	57	.001
Pair 9	F2 - F5	2.7069	11.59251	1.52217	-.3412	5.7550	1.778	57	.081
Pair 10	F2 - F6	-11.4310	13.12572	1.72349	-14.8823	-7.9798	-6.632	57	.000
Pair 11	F2 - F7	-9.4655	13.23103	1.73732	-12.9444	-5.9866	-5.448	57	.000
Pair 12	F3 - F4	.4310	8.40449	1.10356	-1.7788	2.6409	.391	57	.698
Pair 13	F3 - F5	9.0517	14.18848	1.86304	5.3211	12.7824	4.859	57	.000
Pair 14	F3 - F6	-5.0862	10.27394	1.34903	-7.7876	-2.3848	-3.770	57	.000
Pair 15	F3 - F7	-3.1207	11.35407	1.49086	-6.1061	-.1353	-2.093	57	.041
Pair 16	F4 - F5	8.6207	13.93069	1.82919	4.9578	12.2836	4.713	57	.000
Pair 17	F4 - F6	-5.5172	11.43439	1.50141	-8.5238	-2.5107	-3.675	57	.001
Pair 18	F4 - F7	-3.5517	12.83659	1.68553	-6.9269	-.1765	-2.107	57	.040
Pair 19	F5 - F6	-14.1379	15.38220	2.01978	-18.1825	-10.0934	-7.000	57	.000
Pair 20	F5 - F7	-12.1724	14.48064	1.90140	-15.9799	-8.3649	-6.402	57	.000
Pair 21	F6 - F7	1.9655	6.34938	.83371	.2960	3.6350	2.358	57	.022

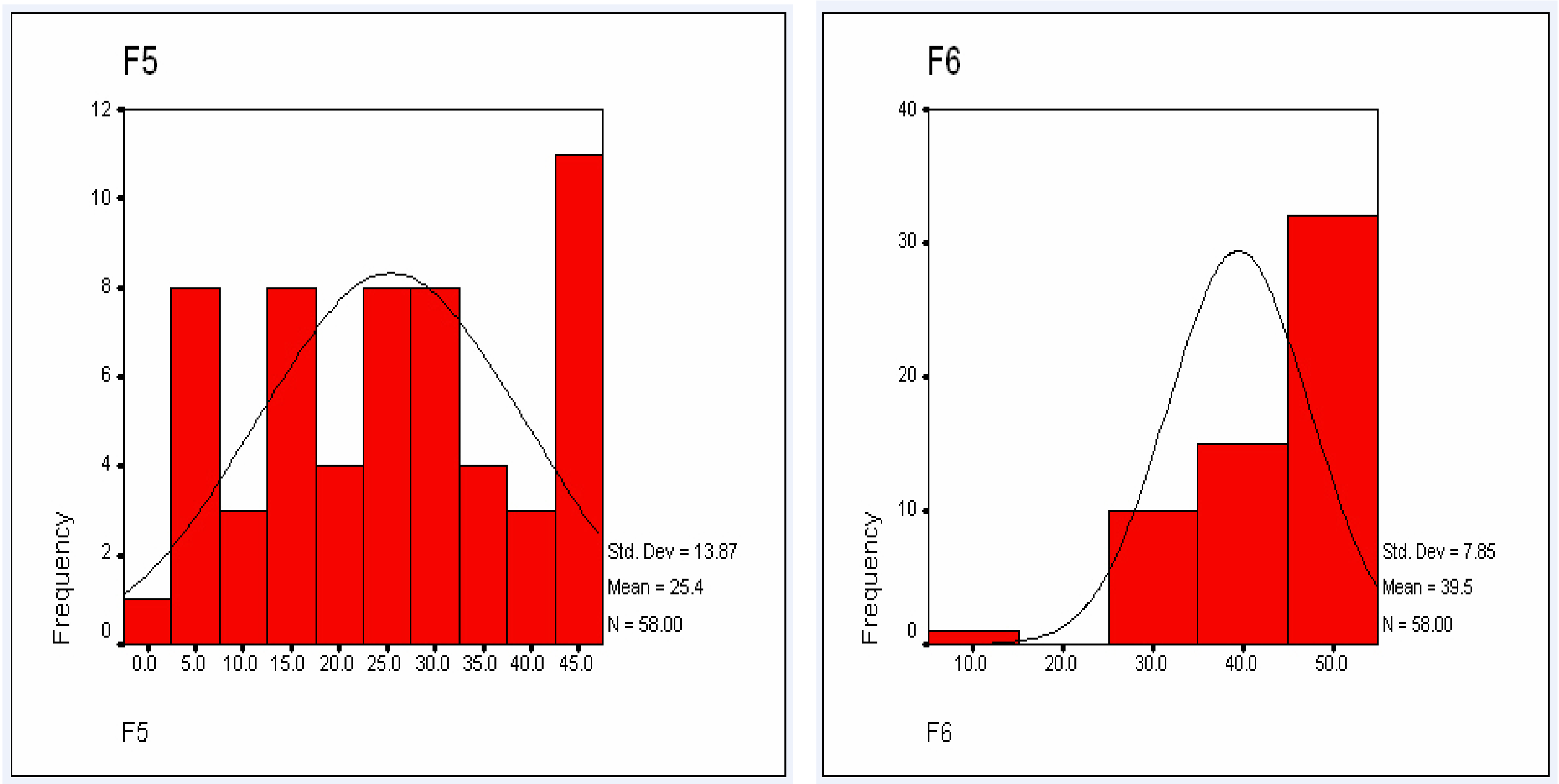


Frequency plots of *Adequate Policy Service (F1) and Service Ease of Use Criteria* critical-to-trust ratings

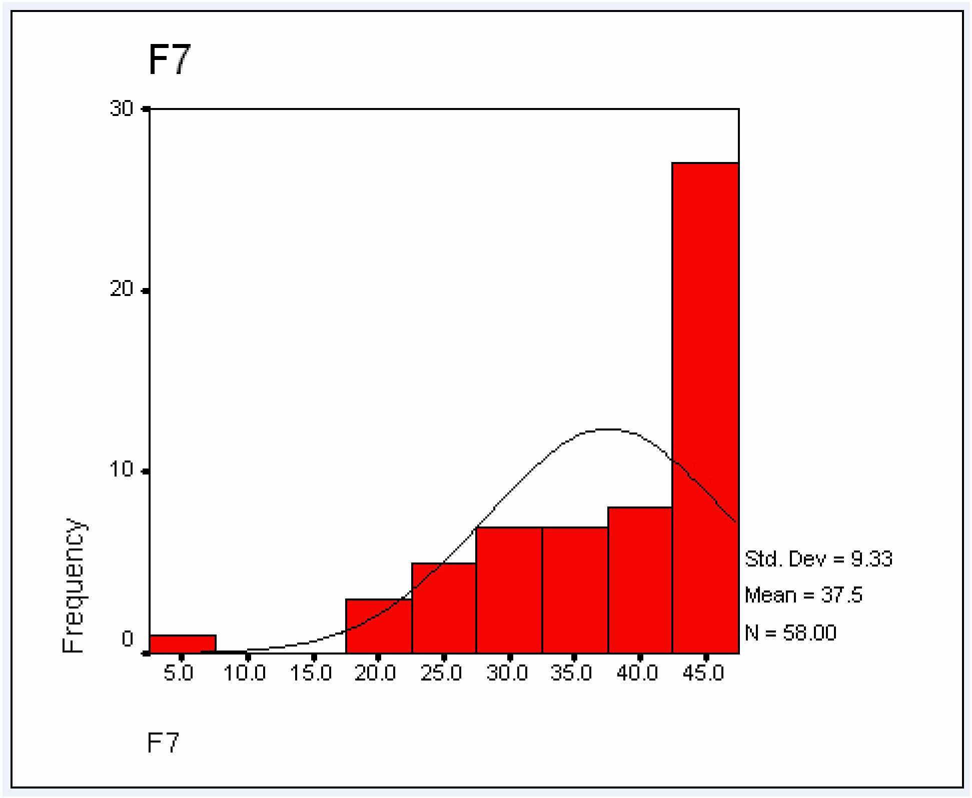




Frequency plots of *Service Conflict Resolution (F3) and Service Response to Deadlines (F4) Criteria* critical-to-trust ratings



Frequency plots of *Previous User's Service Inclination (F5) and Service Quality (F6) Criteria* critical-to-trust ratings



Frequency plots of *Overall Service Evaluation (F7) Criteria* critical-to-trust ratings

APPENDIX D

DATA FROM OTHER RESEARCH STUDIES

The CIO Insight Research Study [130] was conducted with IT executives and the following are the perceived results.

* Vendor capabilities and reliability matter more than cost:

Capabilities are especially important for financial service firms, at 47% for core platform vendors and 51% for niche product vendors.

Lowest price is the top consideration only for commodities.

1.1 Which is the most important factor when making decisions about vendors? (top 5 responses)

N≥282

	total	under 1,000 employees	over 1,000 employees
CORE PLATFORM VENDORS			
Capabilities/Breadth of products	35.2%	29.5%	41.5%
Reliability	22.1	24.4	19.7
Adherence to standards	11.7	12.2	11.3
Value for the money	9.1	10.3	7.7
Reputation	6.4	8.3	4.2
NICHE PRODUCT/SERVICE VENDORS			
Capabilities/Breadth of products	35.3%	31.3%	39.7%
Reliability	17.7	19.1	16.2
Adherence to standards	13.4	13.6	13.2
Value for the money	7.1	6.1	8.1
Financial health	5.3	4.8	5.9
COMMODITY PRODUCT/SERVICE PROVIDERS			
Lowest price	23.1%	22.6%	23.5%
Reliability	22.0	23.3	20.6
Adherence to standards	16.7	15.8	17.6
Capabilities/Breadth of products	12.1	9.6	14.7
Value for the money	10.3	9.6	11.0

The importance of response time:

1.2 Which of the following issues are extremely important for your company when negotiating with a vendor? (top 10 responses)

N≥292

	total	under 1,000 employees	over 1,000 employees
Guarantee response time to problems	70.1%	65.0%	75.9%
No disabling code (“Trojan horses” or “time bombs”)	62.5	61.0	64.1
License continues in event of vendor bankruptcy	62.1	60.4	64.1
Guaranteed defect minimums (i.e. downtime)	49.7	50.3	48.9
No/Low fee for forced move to new platform/version	42.9	38.1	48.2
Guarantees of best pricing	42.5	36.8	48.9
Minimizing support costs	39.8	39.4	40.3
Guaranteed upgrade pricing	36.1	31.0	41.7
Right to switch hardware platforms at no cost	33.6	31.0	36.5
Negotiated license not altered by shrinkwrap licenses	30.1	20.9	40.4

The study found that IT executives are less happy with their vendors than they let on. The results suggest that there is a resignation to a certain level of dissatisfaction. Also, the executives feel they can do little to improve vendor service provision.

2.1 Please indicate the degree to which you agree or disagree with the following statement:

N=289

	total	under 1,000 employees	over 1,000 employees
IT VENDORS SEEK TO PROVIDE THE BEST POSSIBLE VALUE.			
Strongly agree/Agree	76.5%	76.8%	76.1%
Strongly disagree/Disagree	23.5	23.2	23.9
WE HAVE A POSITIVE RELATIONSHIP WITH OUR IT VENDORS.			
Strongly agree/Agree	96.2%	94.7%	97.8%
Strongly disagree/Disagree	3.8	5.3	2.2
OUR VENDORS' PRICES FAIRLY REFLECT THE VALUE WE RECEIVE.			
Strongly agree/Agree	68.9%	71.5%	65.9%
Strongly disagree/Disagree	31.1	28.5	34.1
VENDOR CONTRACTS TODAY ARE BIASED TOWARD VENDORS.			
Strongly agree/Agree	68.5%	66.9%	70.3%
Strongly disagree/Disagree	31.5	33.1	29.7
WE HAVE THE UPPER HAND IN VENDOR CONTRACT NEGOTIATIONS.			
Strongly agree/Agree	61.9%	58.3%	65.9%
Strongly disagree/Disagree	38.1	41.7	34.1
IT VENDORS GENERALLY MEET THEIR COMMITMENTS.			
Strongly agree/Agree	70.6%	70.9%	70.3%
Strongly disagree/Disagree	29.4	29.1	29.7

Only one third of healthcare IT execs agree—far fewer than other industries.

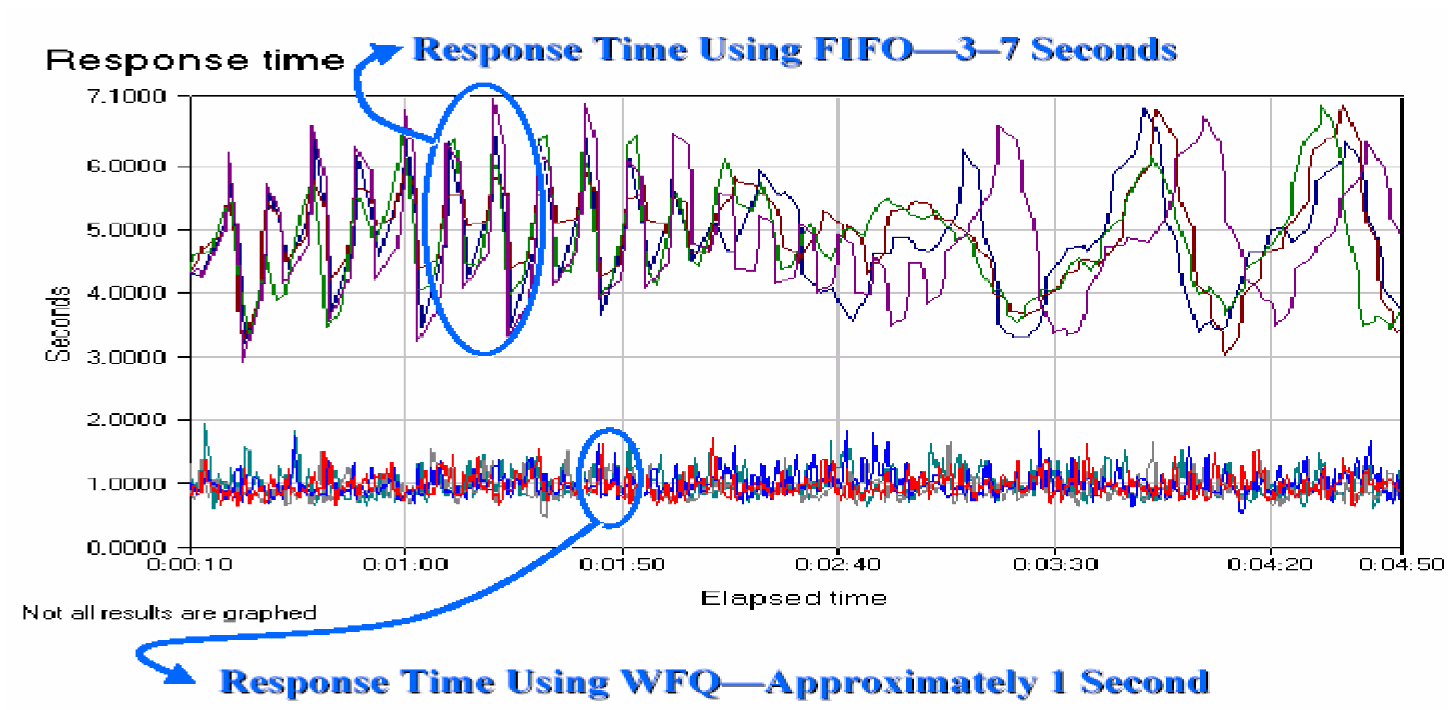
Response to time requests has high dissatisfaction ratings:

2.5 How satisfied are you with the following in your IT department's major IT vendor relationships?	HIGHLY SATISFIED/SATISFIED			DISSATISFIED/HIGHLY DISSATISFIED N≥281		
	total	under 1,000 employees	over 1,000 employees	total	under 1,000 employees	over 1,000 employees
Adherence to service level agreements (SLAs)	91.2%	92.5%	89.9%	8.8%	7.5%	10.2%
Technical specifications met	90.5	90.6	90.5	9.5	9.5	9.5
User satisfaction	85.2	85.1	85.3	14.8	14.9	14.7
Performance (on time, meets specs, etc.)	83.2	83.1	83.3	16.8	16.9	16.7
Warranties	81.1	80.8	81.5	18.9	19.2	18.5
Product reliability and quality	81.9	80.3	83.7	18.1	19.7	16.3
ROI of product or service	75.6	79.5	71.5	24.4	20.6	28.5
Price	70.5	73.7	67.2	29.5	26.4	32.9
Response time to requests	65.7	64.2	67.4	34.3	35.8	32.6

There is more dissatisfaction with response time—the top issue when negotiating with vendors—than any other factor.

IBM Response Time/Quality of Service Study [131]:

Allowing customers to extend business application priorities across the network, the Policy Agent in OS/390 and the Weighted Fair Queuing (WFQ) technology in Cisco IOS software work together to provide end-to-end QoS. The result can be a competitive advantage that improves customer care. For example, a manufacturing company could prioritize "just in time" orders in its messaging system when communicating with suppliers. This joint test with IBM S/390 Enterprise Servers, Cisco networking routers and switches, and IBM Host Integration desktop products demonstrates the benefits of prioritizing IP traffic end to end. Prioritizing IP traffic provides the predictable IP performance required by most service-level agreements and meets the demands of today's e-business applications. The ability of the S/390 Enterprise Server to assign application traffic priority coupled with the ability of Cisco routers and switches to enforce QoS throughout the network ensures that users receive predictable response times even when operating in mixed-traffic environments.



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