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ABSTRACT

DEVELOPMENT AND INTEGRATION OF A DECISION SUPPORT SYSTEM FOR ELECTRONIC OUTSOURCING INTO TELEMUFACTURING SERVICE PROVIDER

**by
Vikram Batra**

The use of computers and Information Technology enables manufacturers, especially small and medium size enterprises (SMEs) to improve productivity and increase manufacturing flexibility. Telemufacturing or manufacturing in virtual environment is one of the infrastructures that facilitate the use of information superhighways and computer technology to attain these goals. Broadly defined, Telemufacturing is the utilization of services accessed via communication networks and across information superhighways to perform in real time, operations and processes essential to the design and production of items. It can be a key enabler for decentralized manufacturing using global resources and expert design teams. In addition to updating several of the existing modules of the Telemufacturing infrastructure developed earlier, in this work an Electronic Outsourcing Decision Support System (DSS) is developed to aid manufacturers in establishing first cut outsourcing policies. The development of this DSS is motivated by the increasing use of outsourcing in businesses today to accomplish improvements in critical success factors such as quality, productivity, customer satisfaction, time to market, and to focus on one's core competencies. The salient features of the DSS are cost analysis and engineering economy procedures to aid users in Telemufacturing decisions as well as for appraising the value of capital investment alternatives. Further, the user-friendly environment inherent to the DSS makes analytical decision making simpler.

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A DECISION SUPPORT SYSTEM FOR ELECTRONIC
OUTSOURCING INTO TELEMUFACTURING SERVICE PROVIDER**

**by
Vikram Batra**

**A Master's Thesis
Submitted to the Faculty of
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Master of Science in Industrial Engineering**

Department of Industrial and Manufacturing Engineering

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APPROVAL PAGE

**DEVELOPMENT AND INTEGRATION OF
A DECISION SUPPORT SYSTEM FOR ELECTRONIC
OUTSOURCING INTO TELEMUFACTURING SERVICE PROVIDER**

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To my beloved family

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CHAPTER 1

INTRODUCTION

1.1 Overview

The concept of remote monitoring and controlling of manufacturing and service operations is not new. However, it has continuously been redefined. Companies such as Schlumberger, GE medical systems, and GE Aircraft Engines remotely support their businesses using state-of-art technology and managing their global resources from a centralized expert center that acts as the main control unit. The development of the World Wide Web (www) and the Internet has further accelerated the possibilities of Tele-control or monitoring activities using the information superhighways. Big industrial conglomerates like General Motors, General Electric, Allied Signal and Caterpillar have benefited from these advances and developed powerful global systems to help them perform with greater efficiency. Additionally, the emerging global digital economy allows for establishing and supporting a two-way information link between a company and its customers through remote and asynchronous mechanisms¹. This link is possible not only for consumer products and services but also for business-to-business products and services. In this regard, the Telemufacturing concept or the concept of manufacturing using the Information Superhighways and the web technology is believed to effectively address the flexibility, affordability and adaptability issues facing producers in general today. A definition coined by Abdel-Malek et al is, “Telemufacturing is a structure whereby a company can outsource several of its production and design activities particularly via the information superhighways”². To be more precise,

Telemanufacturing is the utilization of services accessed via communication networks and across information superhighways to perform, in real time, operations and processes essential to the design and production of items. The aim is to develop an infrastructure that acts as a vehicle to raise the standard of living through productivity improvement that comes about by sharing information-based resources. The Telemanufacturing concept enables development of new ways for enhancing design and manufacturing productivity by sharing globally available information and resources using the Internet. It effectively makes use of the advances in information technology to aid the manufacturers in critical design and manufacturing decisions. According to Prahalad and Hamel, effective contracting for complementary capabilities through a network of suppliers and sub contractors is a characteristic of virtual organizing³. However, despite the improvements and advances that can be afforded through Telemanufacturing, there are many issues that need to be addressed for a wider application of these technologies particularly for SMEs. In this regard, to improve the functionality and utilization of this concept, a Decision Support System for Electronic Outsourcing decision making has been proposed to aid users in developing their sourcing strategies and decide whether to Telemanufacture a part or a service or to manufacture it in-house.

1.2 Background Information

The Telemanufacturing concept provides a framework for suppliers, customers and manufacturers located globally to interact and make use of advances in technology available worldwide. It enables the integration of expertise and equipment that exists in government, college and private research centers into factory floor activities of the

manufacturers. Utilizing world class technology and expert knowledge, Telemanufacturing can provide a useful resource center for multi-site manufacturing. A possible infrastructure for Telemanufacturing is shown in figure 1.1. It consists of an In-house Controller (IHC), a set of Specialized Expert Centers (SEC) and a Team Expert Center (TEC).

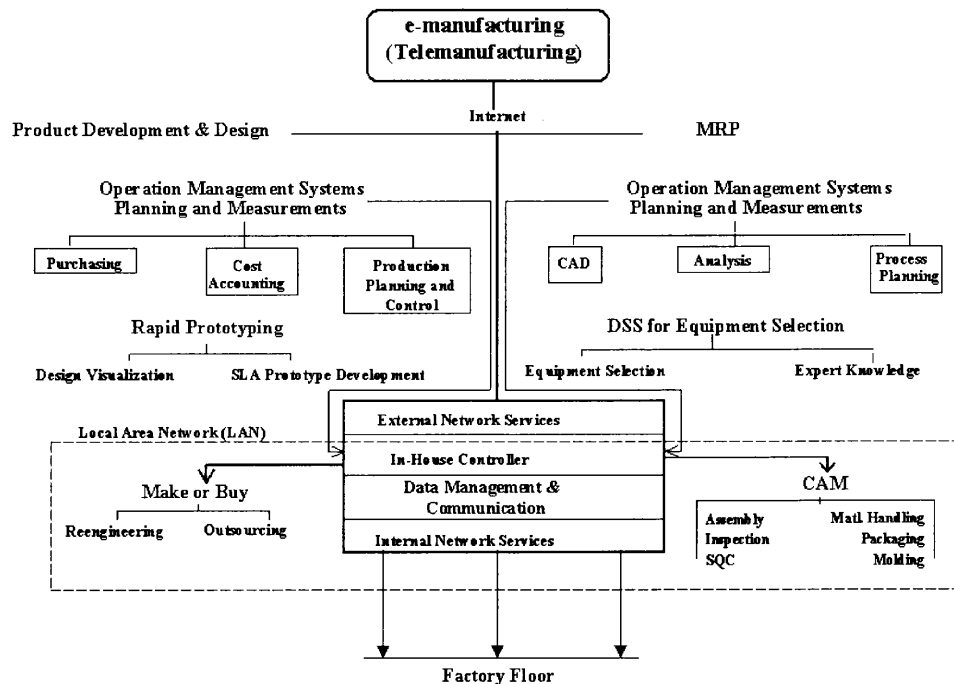


Figure 1.1 Infrastructure for a Telemanufacturing Enterprise

The IHC is an essential control component that integrates the expert centers, manufacturing floor activities, and other functions. It also helps in the execution of processes in accordance with the laid out rules and regulations. The IHC is made up of an in-house team and computers having databases, required software, and modules that interact with the different SEC's. In short the IHC is the brain of the Telemanufacturing enterprise. The second component called the Specialized Expert Center (SEC) possesses

the state of art in a certain field. The SEC's can provide services ranging from product design, process planning, materials management to production scheduling. SEC's enjoy advanced expertise in their respective fields and have access to the latest available information and development. For linking the SEC with the in-house controller a communication media is required. There are two types of media necessary for the Telemanufacturing enterprise, one for within the enterprise connections and the other for outside communication. The Internet is a good choice for external communication and can enable interaction between the IHC and the different SECs. The internal communication could be carried out using a Local Area Network (LAN). In general a remote-manufacturing infrastructure such as the one at the New Jersey Institute of Technology incorporates the following features.

- 1). Supervisory Controller: The controller coordinates, controls and monitors the functioning of the whole enterprise. This system is adept in decision-making and trouble shooting.
- 2). Multi-Site Integrated Monitoring: A globalized integrated manufacturing structure ensures decentralized manufacturing and control of activities and processes occurring on different sites.
- 3). Communication Media: A remote manufacturing system uses a communication media such as the Internet for accessing information and other technology available globally. Companies normally use a LAN/WAN for within the enterprise communication.
- 4). Expert Knowledge Base: A remote manufacturing system always keeps on improving, learning from the experiences of its users. The system houses knowledge base that is updated regularly to keep pace with the rapidly changing market needs.

An example of the Telemanufacturing or the Virtual Manufacturing concept has been the Rensselaer's Electronics Agile Manufacturing Research Institute (EAMRI) that has made considerable progress in this field. It used a cutting edge technology called Virtual Designer Environment (VDE) which bases design and manufacturing decisions not on the limited information available to one person, at any one time, but on agile intelligent autonomous agents seeking information available within a distributed database system. EAMRI's Virtual Designer Environment produced an optimal design for Pitney Bowes controller boards by accessing via the Internet, component supplier databases from Pitney Bowes and Lucent Technologies and cost profile and design rule databases from Hughes Missile Systems in Tucson, AZ., as well as board fabrication and assembly cost databases supplied by Lucent. Thus using VDE, EAMRI was able to design, manufacture and test printed circuit boards within the boundaries of their research lab. The results of this were reduced lead times, fewer delays, cost savings, and at the same time simplified decision-making. VDE also includes design evaluation models that the designer can use to assess how well the different options fit together. A model called the Design for Producibility (DFP) is also available, which examines the feasibility of automated machine placement of components and also includes various embedded rules to check designs. VDE can also evaluate the design for material and manufacturing costs as well as cycle times. This evaluation relies on access to collaborating supplier databases for up to date cost models and data. Critical information on component availability may also be obtained by the designer to better support design decisions on component specifications.

1.3 Contribution and Organization of the Work

The aim of this work is to further build on the nucleus for the Telemanufacturing enterprise and develop a decision model to enable companies to decide whether to Telemanufacture a part or a service or to produce it in-house. An Electronic Outsourcing scheme that forms a critical component of a Telemanufacturing enterprise has been developed. This DSS enables companies to determine their sourcing policies efficiently. It helps in evaluating alternative new technological proposals for capital investments by using Engineering Economy procedures and also enables users to carry out a costing of their production and purchase activity in order to determine a more efficient and economical method of completing a job. This decision tool is developed using Visual Basic and JavaScript and has been integrated with the existing Telemanufacturing web site to be accessed by authorized users. The Electronic Outsourcing DSS incorporates procedures for Engineering Economy studies, Cost Analysis for Production and Purchase, Break Even Analysis and a Performance Index for the Intangible factors associated with the Outsourcing activity. In this regard, the Telemanufacturing web site, the main service provider for the available facilities has been dealt in greater detail in chapter 5. Additionally, the capabilities of the Telemanufacturing web site have been further enhanced and made more informative and educative about the concept of Telemanufacturing. An infrastructure required for the Rapid Prototyping system has also been suggested. This work was also aimed at improving awareness towards the concept of outsourcing and how companies can benefit from it. In this regard some successful experiences of corporations with outsourcing have been highlighted.

The contents of this thesis are organized as follows. Chapter 2 is the literature review of the existing company trends towards outsourcing and a general outlook of the Outsourcing industry. Also included in this chapter are the real company experiences in the field of outsourcing. In this regard focus has been laid on reasons companies outsource and the strategies that are adopted to achieve successful outsourcing. Chapter 3 deals with the Outsourcing industry in greater detail and highlights the importance and impact of the World Wide Web in electronic outsourcing and its effect on the productivity and flexibility of companies. Chapter 4 deals with the proposed Electronic Outsourcing Decision Support System. This chapter discusses the factors and the issues that were considered in developing the decision model and the analysis procedures that this model incorporates. The chapter also discusses the working of the DSS that is in the form of software. Two case studies have been considered to show the relevance of the decision software. Chapter 5 focuses on the Telemanufacturing web site that is being updated frequently. Finally, chapter 6 provides the summary and conclusions and includes areas for future work. The appendix section includes a user manual for the Electronic Outsourcing DSS.

CHAPTER 2

LITERATURE REVIEW AND OUTSOURCING EXPERIENCES

Outsourcing of components and sub assemblies is emerging as a key strategy for companies seeking competitive advantages in the global environment. Among valid reasons that drive manufacturers to outsource are lower cost, available capacity, quality, and access to latest technology. However, according to Davis, lower price ranks highest among all possible reasons ⁴. Drastic cost advantages provides strong motivation for companies to seek sourcing arrangements in environments with significant price uncertainties. The outside service provider specialists can develop greater knowledge depth, invest more in technology and training systems, be more efficient and attract more highly trained people to do the job. Quinn, et al have stated that a properly developed, strategic outsourcing substantially lowers costs, risks and fixed investments while greatly expanding flexibility, innovative capabilities, and opportunities for creating higher value-added and shareholder returns ⁵. Another major reason, according to Carter and Vickery, is the fluctuations in the money value of different currencies, where the buyer can end up paying substantially more or less than original contract price ⁶. Further Austin feels that extreme conditions of inflation in some developing countries also contribute to volatility of sourcing prices from local suppliers ⁷. The rigid and difficult-to-forecast capacity conditions in fast growing industries combined with fluctuating prices of material and process technologies further contribute to development of outsourcing relationships. For further markets to exist, Telser states that there must be a certain amount of standardization in the underlying commodity, which is not a feature of many commonly

used industrial practices⁸. Under such prevailing sourcing environments, Carter and Vickery and Dornier et al are under the impression that it is not uncommon that a supplier will offer supply contracts with risk sharing features to its buyers^{6,9}.

2.1 General Outlook of the Outsourcing Industry

The research in the field of outsourcing shows that the outsourcing industry in the US particularly is growing at a fast pace. More companies are considering outsourcing in order to become competitive in today's global economy. Outsourcing, is being viewed as an important medium to achieve strategic goals such as cost reductions, improving customer satisfaction, reduction in time to market and for other efficiency and effectiveness improvements. In the past, however, there were conflicting views to the idea of using an outside service provider as a part of the business. This trend has changed quickly. Coase has remarked that if supplier markets were totally reliable and efficient, rational companies would outsource everything except their core competencies¹⁰. Today's competitive market has completely changed the earlier existing negative view of outsourcing. Companies have started considering this issue with an aim to achieve objectives like:

1). Accelerating Reengineering Benefits: The concept of Process Reengineering aims at achieving dramatic improvements in critical measures of performance such as cost, quality of service and speed. But this need to increase efficiency comes into direct conflict with the need to invest in core businesses. As a result getting rid of non-core activities becomes important and by "the delegation of one or more business processes to an external provider who then owns, manages, administers the selected processes based

measurable metrics”¹¹, an organization can begin to see the benefits of reengineering at a much faster pace.

2). *Accessing World Class Capabilities*: Large industrial conglomerates like Boeing, Ford, AT&T, Mobil have realized that in order to remain innovative in today’s market, it is very important as well as advisable to be flexible and use the expertise, and innovation available with world wide knowledge sources. Ford has gone from 70 percent in-house production to 70 percent outsourcing, BMW is outsourcing 80 percent of all part manufacturing and Boeing outsources its entire electronic designing ¹².

3). *Retaining Business focus*: Outsourcing enables a company to focus on its core business by having operational functions assumed by an outside service provider. Core competencies are the essential and enduring tenets of an organization. They require no external justification and have intrinsic value and importance to those inside the organization. A company decides what values it holds to be the core, largely independent of the current environment, and competitive requirements. Only a few values can be truly core and are so fundamental and deeply held that they will seldom change. These core values guide the business decisions and the day to day functioning of an organization. Further Coase has stated that rationale companies will outsource everything except its core business. This will allow the company enough freedom to focus on its resources to meet customer demands.

4). *Freeing Resources for other purposes*: Every organization has limits on the resources available to it. Even big companies have a limit on the resources they possess. It is very important to use these limited resources in the most appropriate manner and use technologies that exists some where else rather than trying to develop everything on ones

own. Outsourcing enables an organization to redirect its resources, from non-core activities towards activities that are core to the business and affect the customer directly.

5). *Functions difficult to manage or Out of Control:* Outsourcing is one of the options available for taking care of functions that are difficult to manage. In most cases a company will be better off by utilizing an outside provider for functions that are difficult to handle.

6). *Making capital funds available:* One of the most important decisions that senior management makes is to decide where to invest the limited available capital funds. Very often it is hard to justify non-core capital investments when there are functions directly related to producing a product or service to take care of. Outsourcing can reduce the need to invest capital funds in non-core functions and thereby freeing funds for the core activities.

7). *Reduce Operating Costs:* Companies that try to do everything themselves may incur very high research, development, and marketing costs, all of which are passed on to the customer. An outside provider's lower cost structure reduces a company's operating cost and increases its competitive advantage.

8). *Reduce Risks:* Tremendous risks are associated with the investment an organization makes. Markets, competition, government regulations, financial conditions and technologies all can change extremely quickly. If executed properly, Outsourcing can both decrease costs as well as lower the risks involved in the business, by sharing it with the service providers.

While outsourcing can provide a major financial boost, proper care must be taken in the selection of partners to ensure that the relation moves smoothly and without

problems. Nevertheless, most supplier markets do entail some risks for the both the buyer and the seller and some unique transaction costs for searching, contracting, controlling, and re-contracting ¹³. An effective and intelligent outsourcing relationship is therefore critical for both parties, i.e. the service provider and the company that outsources. In chapter 3 some of the critical factors to be taken care of for the proper management of an outsourcing relationship have been highlighted.

2.1.1 Present Trends in the Outsourcing Industry

A lot of research is being carried out to predict the future of this industry and as to how it can affect our businesses. According to business consultants Dun & Bradstreet and the Outsourcing Institute (an institute specializing in outsourcing research) ¹⁴:

1. There has been a 27% increase in the outsourcing activity in 1998 over the 1997 figure.
2. Outsourcing practices in information services are growing faster than any other sector.
3. Companies using outsourcing services are financially more stable.
4. The number of projects in the planning stage is nearly twice the number presently being administered.

The study also suggests that US companies with over \$80 million in revenue expect to increase expenditures for services they outsource by 26%. As far as which industries are most likely to use outsourcing are concerned, figure 2.1 shows manufacturers account for nearly two-thirds of all outsourcing. Durable manufacturers account for 36% of all

outsourcing activity while non-durable manufacturers account for 26%. Information services including telecommunications

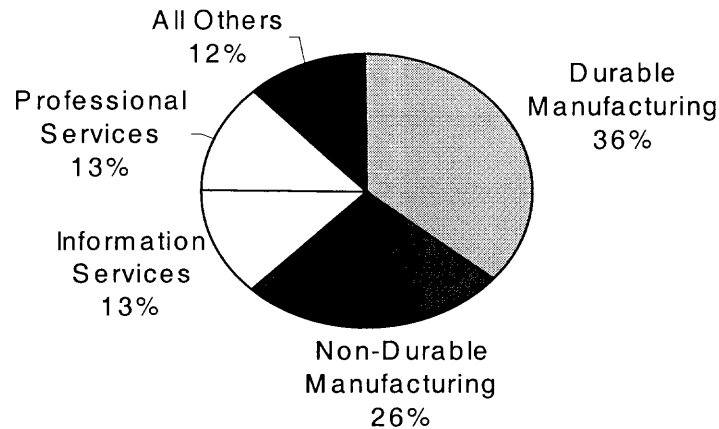


Figure 2.1 Present Trends in Outsourcing Industry

and technology companies consume 13% of all outsourcing activity. In addition, Information Services is increasing its use of outsourcing faster than other industries with a growth of over 50% annually.

2.2 Real Life Company Experiences in Outsourcing

This section focuses on outsourcing contracts undertaken by companies. It also discusses how careful selection of suppliers, type of sourcing contracts, purchase quantities from suppliers, and the timing of purchase can effectively reduce the expected sourcing costs. Illustrated in the following paragraphs are case studies of companies that decided to outsource their functions to gain competitive advantage and reduce their costs.

2.2.1 Honeywell-Hadco Collaboration

Honeywell, a large electronics firm, after reassessing its make or buy decisions and reducing its supplier base, entered into a collaborative contract with Hadco, a New Hampshire based corporation for the manufacture of printed circuit boards. Hadco formed a close working relationship with Honeywell's industrial programmable controls operation. It purchased new equipment to solder at high volume in high-quality lots. It also installed an advanced system that allowed for finer line drawings in producing double and triple track circuits. The two companies combined their engineering, quality control, and materials groups to ensure that Hadco was able to deliver defect free products on time. Together they brought about a 60 percent reduction in board size and a 90 percent saving in board weight ¹⁵. Along with these savings, they were able to achieve higher board performance and reliability as well as greater opportunities for automation and cost savings. Honeywell was able to concentrate more on developing new circuit board designs and outsource the actual manufacturing to Hadco. As a result, the sourcing arrangement enabled Hadco to become a global manufacturer of circuit boards and at the same Honeywell was able to save a lot of cost on manufacturing and technology investment.

2.2.2 General Motors-Sundaram Fasteners Sourcing Arrangement

General Motors outsourced the production of radiator caps used in the manufacture of its North American vehicles to India's Sundaram Fasteners. For Sundaram, a medium sized enterprise with manufacturing units in the southern part of India, it was a good opportunity to become a world class supplier and establish its identity outside of India.

To accomplish this, Sundaram bought an entire General Motor's production line and moved it to India. The advantage of participating in GM's supply network made it easier for Sundaram to develop its capabilities and learn about emerging technical trends and quality standards. The result of this relationship was that Sundaram was approved as a QS 9000 supplier, a certification required by all GM suppliers, within a year. General Motors made Sundaram the sole supplier of all radiator caps to its North American division. By supplying 5 million caps a year, Sundaram was able to meet all of General Motor's demand and also enabled them to save a lot on time and money that would have been spent for carrying out the production of radiator caps ¹⁶. The outsourcing relationship has benefited Sundaram so much that it has made it capable enough of supplying radiator caps to automobile factories all over the world.

2.2.3 Case of the Largest Chemical Company: DuPont

A few years ago, a decision was taken by the world's major nations to stop the production of chlorofluorocarbons (CFCs), compounds commonly used in refrigerants, aerosol, propellants and solvents. This created a serious problem for DuPont. The company had invested a lot of resources in researching and manufacturing CFCs. DuPont was faced with an immediate need to develop CFC alternatives quickly in order to maintain its market domination. To achieve this and also to figure out the best way to produce CFC substitutes, DuPont outsourced research to more than 20 organizations, including academic institutions, research centers and private companies. They outsourced only \$5 million of \$400 million they had spent on CFC research, but the company was able to save much more money by not doing the research in-house. It would have cost the

company 10 times more than what they paid to their research partners if they had done everything in-house ¹⁷. To DuPont, even more important than saving money was the speed to develop CFC substitutes. The main aim was to develop alternatives before the CFC ban was implemented. By outsourcing the research activity, DuPont was able to access the expertise and equipment that they did not have time or money to invest in. The result was that DuPont was able to cease production of CFCs three years before the deadline came into effect and today it sells CFC alternatives in five different product areas, including refrigeration, propellants and cleaning agents. Outsourcing thus helped DuPont to address the challenges of faster cycle times, changing technology and skill shortages.

2.2.4 Kodak's Outsourcing Arrangement

In 1989, Kodak entered into an outsourcing arrangement with IBM for providing Information Technology (IT) services. This was considered a new development in the IT Management industry because large companies used to provide their own IT support. The main reason that led to this \$250 million collaboration was the realization of economics and perceptions associated with the outsourcing concept. Kodak's Information Systems department had expanded to almost unmanageable levels and its budget had grown to \$250 million of which \$90 million were being spent for capital expenditures ¹⁸. The company was investing money in functions that were not even their core competencies. The management realized that they had to get rid of their IT functions, if they were to concentrate more on their core competencies and achieve cost savings. To accomplish this they signed up an outsourcing deal with IBM to take up their IT

operations. IBM created a new business unit called Integrated Systems Solutions Corp. (ISSC) and built a whole new state-of-art data center at Kodak headquarters. The people employed by IBM for ISSC were taken from Kodak itself that made it easier to understand the functioning of the whole system. The deal resulted in immediate positive results for Kodak. Kodak's IT capital expenditures were reduced by approximately 95 percent, the PC support costs by 10 percent and mainframe operations costs dropped by 10 to 15 percent. This deal, that was signed almost 10 years back has been renewed for another 6 years because of the cost savings and better business control that Kodak has been able to achieve due to it.

In addition to the above-considered cases, there have been many other outsourcing activities involving both big as well as small and medium size enterprises that have helped companies to gain competitive advantage. Ford has increasingly used Asea Brown Boveri (ABB), a globalized technology and engineering company, to develop new plants at 70 percent of its usual in-house costs. Nike outsources almost all its production to its alliances in Asia and South America to gain access to cheap manpower and technology and thereby enabling itself to concentrate more on research and development. Outsourcing can therefore help corporations achieve quick improvements, but it is critical that companies make correct decisions regarding their sourcing strategies and decide intelligently whether to keep a function in-house or to Telemanufacture it. It should be carried out in a systematic manner and good care should be taken in the selection of vendor. A performance evaluation of the vendor at regular periods of time is critical to ensure benefits to ones business. Factors to be considered while entering into an

outsourcing agreement have been dealt in chapter 3. Further, a decision support system for making outsourcing decisions has been discussed in chapter 4.

CHAPTER 3

ELECTRONIC OUTSOURCING AND THE WORLD WIDE WEB

This chapter deals with the concept of Outsourcing in more detail and highlights the impact and importance of the World Wide Web in Electronic Outsourcing and its effect on productivity and flexibility of companies. Further, the chapter also discusses the critical factors that can help to ensure a successful outsourcing relationship. Also dealt in this chapter are some of the problems that may surface in an outsourcing relationship and the possible solutions to these problems.

3.1 Growth of the Internet Use

The rapid growth in the adoption of Information Technology and the easy access to fast and powerful computers have enabled manufacturers and service providers to utilize the cyberspace to improve productivity and enhance flexibility. The Internet has completely changed how businesses are run. According to a study conducted by the University of Texas's Center for Research in Electronic Commerce, the Internet economy in the US generated an estimated \$301.4 billion in revenues in the year 1998 ³. Another study by Forrester Research, a leading Internet consultancy, stated that by 2003 the E-Commerce business will jump to \$1.3 Trillion, that is 9% of all US business trade and more than the gross domestic product of either Britain or Italy ¹⁹. These figures provide an important justification to the fact that the Internet is playing a very important role in shaping the overall US economy.

General Motors realizes that for it to be successful and for it to compete globally in the car market, it also needs to be competitive enough in the electronic business market. GM recently began its online car-shopping service at www.gmbuypower.com and within a month it attracted a large number of customers. With the number of customers researching new-car purchases on the Internet continuously increasing, GM sees electronic selling as an important medium to further expand its sales. In addition to selling cars, GM is also using the Internet to better understand the customers' preferences that can enable it to produce a vehicle that meets the customers' tastes. Thus for GM, the overall impact of the Internet revolution has been in product development, manufacturing and marketing. Propelled by this success of the telecommuting experiences that some of the larger corporations have had in utilizing these technologies, several initiatives are underway to build an infrastructure that integrates Information superhighways and computer technologies into manufacturing operations. One such infrastructure is Telemanufacturing. The main essence of this infrastructure is a service provider web site that captures the advances made in virtual reality technologies to aid manufacturers particularly the small and medium size enterprises in gaining competitiveness. This service provider web site is addressed in greater detail in chapter 5. The web site provides several manufacturing functions via the Internet and enables firms to outsource activities electronically. Included in this electronic, internet based service provider are certain decision support systems for Flexible Manufacturing System Cell design, technology assessment procedures and electronic outsourcing decisions, as well as access to rapid prototyping equipment for product development.

The following sections deal with the outsourcing industry in general, and are concerned with how to manage an outsourcing relationship, the problems that can surface and how to counter them. Also highlighted are the reasons companies are outsourcing today.

3.2 Definition of Outsourcing

As more and more companies try to expand globally and become more efficient, they visualize outsourcing of non-core functions as an important key to achieving these goals. Quinn has stated that a company should concentrate its own resources on core competencies where it can provide unique value to the customers. Further he adds that core competencies are the activities that offer a longtime competitive advantage. In the same way Porter feels that one should concentrate on technologies that have the greatest impact on cost ²⁰. The results of this outsourcing trend have been dramatic for some companies, enabling them to reduce their workforces and overheads and at the same time enhancing their productivity and efficiency. According to the US Trade Commission Report of 1995, a worldwide outsourcing trend of approximately 12% growth per year is expected to continue with the market predicted to be over \$100 billion in revenues by 1998 ²¹. This will make outsourcing one of the fastest growing sectors and it may make an outsourcing agreement one of a company's largest and most important relationships. By sharing risks with the vendors, outsourcing not only reduces operating costs for an organization but also frees money for capital investments. Companies have found that through outsourcing they can get professional assistance with jobs that require a high degree of knowledge and experience at a fraction of the cost of hiring additional full-time

employees to do the work. However, outsourcing cannot be taken lightly and involves careful planning and study. Considerable time and effort must be spent by an organization in order to maximize the benefits of the outsourcer and to ensure contract compliance.

The term “Outsourcing” has been applied to many different relationships across a variety of business areas ranging from the manufacturing industry, areas of office management to the data processing industry. Simply defined, “ Outsourcing is the practice of contracting job responsibilities to professionals who are more adept at doing it and can focus on the work and get it done quickly, efficiently and accurately”.

According to Baines et al, US companies usually prefer to outsource rather than to produce in-house ²². In the manufacturing industry, outsourcing is most commonly found in contracting for part/component manufacture, prototype development, CAD, CNC, etc. Companies like the manufacturing conglomerates, Ford Motors who were strictly against outsourcing are now more than willing to work with outside vendors ¹⁰. In the areas of office management, the outsourcing of copying centers and service agencies is rapidly gaining momentum. This outsourcing agreement is usually characterized by buying the central copying equipment, providing services in the specified time period, and charging the department by the copy. In the data processing industry it is not uncommon to find the entire data processing infrastructures outsourced such as data centers, application development, help desk, and PC installation and support. Most companies employ multiple outsourcers that supply services in their specialty areas. For example, IBM provides the data center services, and Hewlett Packard might provide UNIX support.

In spite of the wide diversity of outsourced services and processes, outsourcing relationships have remarkably similar characteristics. The first characteristic of an outsourcing contract is that a significant commitment exists between the customer, the person or the company that outsources and the outsourcer, the person or the company that provides the outsourced services.

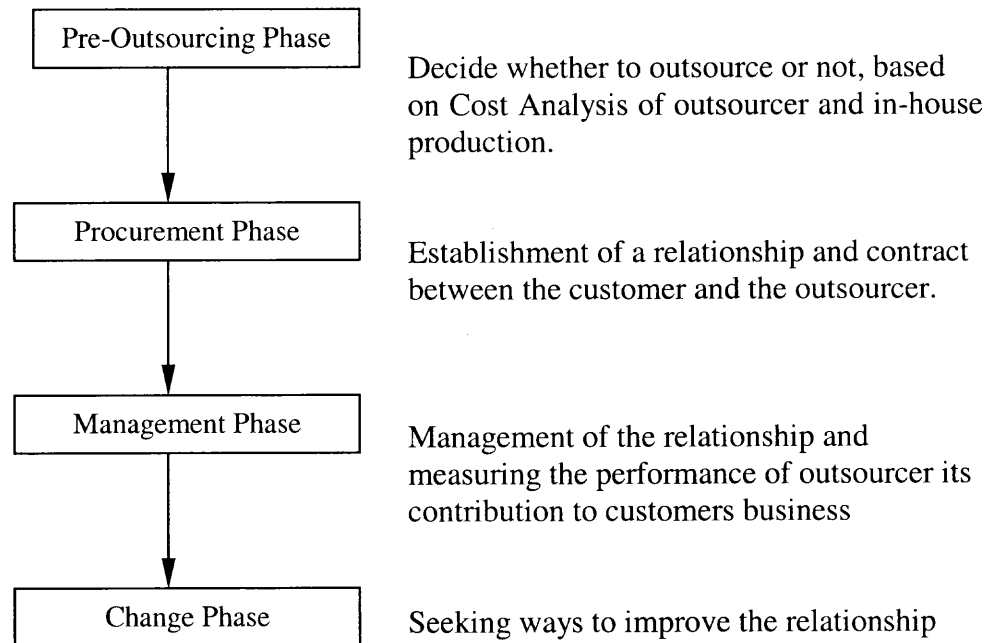


Figure 3.1 Flowchart for Outsourcing Process

A typical flowchart for an Outsourcing Process is shown in figure 3.1²³. For the customer an Outsourcing arrangement may require selling assets to the outsourcer, transferring people, and entering into a relationship in which the outsourcer is the provider of the key services. For the outsourcer, this may involve substantial monetary investment in acquiring assets, absorbing the transferred people, and putting in new facilities, equipment, and systems in order to meet the requirements of the customer's outsourced functions. Both parties often also find that they have to invest in learning the new environment and building interpersonal relationships. Regardless of the process that is

outsourced or the size and complexity of the relationship, all outsourcing relationships require coordination and communication between the parties involved.

3.2.1 Outsourcing in Companies

The potential benefits of outsourcing for a company are enormous. Outsourcing allows a company to lower its costs, turn a fixed cost into a variable cost, release capital for use in other areas, get rid of functions difficult to handle and to accelerate reengineering benefits. Giffi et al are critical of top management teams that attempt to save a few dollars by 'doing it ourselves' ²⁴. They favor outsourcing, appreciating the efforts of Motorola for having a formal policy of 'do not create what already exists somewhere else'. A key benefit of outsourcing is substantial cost reduction of the outsourced commodity. In some cases, these costs are reduced by 20-40%. Outsourcing is especially beneficial in the case of seasonal businesses. The customer is also able to avoid the ongoing re-investment required by infrastructures such as new equipment or facilities because the outsourcer provides that investment as part of its cost. Also when selling assets or transferring people, the customer receives a positive cash in-flow and releases assets for re-deployment elsewhere. However, the greatest benefit of outsourcing is that it allows the management to focus its attention on the core functions of the organization, and allows the outsourcer to focus on improving the professionalism of the service.

3.2.2 Managing an Outsourcing Relationship

Davidow and Malone feel that "for a virtual cooperation to succeed, it must be closely linked with its suppliers as to create a shared destiny. Ultimately, even the boundaries

between them will become indistinct”³⁰. Outsourcing is growing at a rapid rate in the United States, Europe and Asia because organizations view outsourcing as a way to achieve strategic goals, reduce costs, improve customer satisfaction and provide other efficiency and effectiveness improvements. In this regard it is very important to develop a strong and an efficient relationship with ones supplier. Goldman et al highlight the importance of close relationships with suppliers and sub contractors to realize efficiency and flexibility-critical factors of organizational agility³¹. This section outlines some of the critical factors for successful outsourcing management.

1. *Define the Objectives you Want to Achieve:* Outsourcing must be done carefully, systematically, and with well-defined goals. It may be justifiable for a department with high costs that cannot be reduced or a lack of competency in certain areas. Companies may turn to outsourcing with an aim to compete globally or to get relief from financial pressures. It should not be used as an excuse for poorly managed and costly activity. By deciding to outsource for the wrong reason is like giving the outsourcing vendor gains that should have been ones own.
2. *Outsource for the Right Reasons:* Evaluate the potential outsourcing benefits, like cost reduction, improved satisfaction carefully. By outsourcing a function that is not a core competency, the company can pay more attention to functions that are more important.
3. *Address Critical Aspects:* Before entering into a relationship with the outsourcer, the customer must address some critical aspects associated with the function that is being considered for outsourcing. As far as possible, a company should try to keep core activities in-house and not outsource them. It is also very important for the union and

employees of the company to agree with the management's decision for outsourcing for it to be successful. Further, it is important to clearly define the objectives and benefits that a company expects to achieve through outsourcing.

4. *Use a Methodical Approach:* The outsourcing process involves numerous steps. These stages involve identifying requirements, requesting proposals, examining proposals, evaluating vendors, negotiating contracts, and finally implementing outsourcing.

The various phases are as follows:

1. **Pre-Outsourcing Phase:** This is the phase wherein the company has to decide whether to outsource or not. This phase involves decisions such as what parts to outsource, for how long and, on what terms. Typical activities during this stage involve Outsourcing Assessment, Infrastructure Assessment, Goal Setting and Cost Savings Analysis.
2. **Procurement Phase:** This is the phase where the company looks for an outside vendor and enters into a contract. Proper care must be taken while selecting a vendor. Some of the key factors to be considered while selecting a vendor are:
 - a. commitment to quality
 - b. price
 - c. reputation
 - d. cultural match
 - e. location
 - f. existing relationship
3. **Management Phase:** After forming a proper relationship and entering into a contract with the vendor, the next step is to make sure that the relationship

moves smoothly and benefits the customer. This stage is termed as the Management Phase. The company needs from time to time to evaluate the performance and contribution of the vendor to the business. This stage involves activities like :

- a. measuring vendor's performance and cost
- b. provide methodology to achieve continuous improvement and flexibility in the relationship

4. Change Management Phase: Once a smooth relationship has been established with the vendor, the company should try to look for new ways to further improve the relationship as well as the efficiency of the vendor. The company can also look for new vendors in case the present vendor is not able to satisfy the requirements of the customer. Some of the typical activities associated with this phase are:

- a. review existing relationship
- b. review customer expectations
- c. define service levels
- d. negotiate with suppliers
- e. establish appropriate awards and penalties
- f. train customer

Outsourcing therefore should be carried out in a systematically conducted and documented manner.

5. *Get the Right People Involved:* Once the decision is made to outsource, it is important to identify persons who should be given responsibility for the management of the

outsourcing arrangement and vendor relations. Its desirable to involve these people from the offset itself because there is no better way to understand the issues involved in outsourcing than to be involved in all aspects leading up to the deal. Also having a continuing relationship with the people in the vendor organization is a big factor that contributes to success.

6. *Understand the Vendors:* Companies must properly understand the vendors and not be misled by what other organizations are paying or what a vendor might casually offer as possible pricing scheme. After narrowing potential vendors to a manageable handful, better pricing and service agreements can be reached by negotiating with the best two or three vendors and then selecting the best offer among them.
7. *Negotiate a Sound Contract:* One of the critical components of a good outsourcing agreement is a sound and well-laid out contract. Because each aspect of the outsourcing relationship is governed by the contract, both the customer and the outsourcing vendor should agree on every thing. They also need to agree on how to resolve disputes and problems that may surface. Some of the important contract considerations are:
 - a. *Term of the agreement:* This defines the period for which the contract will be effective.
 - b. *Minimum Service Levels:* The contract should clearly establish the minimum acceptable service levels.
 - c. *Ownership and confidentiality of data:* The agreement must specify that the customer retains ownership of the data it submits to the vendor and that the data is kept strictly confidential.

- d. Incentives:* A contract should provide for an incentive for the vendor to perform. Such incentives may include guaranteed savings, shared benefits/risks and profitability index.
 - e. Performance measures:* A sound contract must include performance measures to measure the performance of the vendor and to determine the gains achieved by the customer.
8. *Use Objective Performance Criteria:* The performance measurement criteria must be defined to be easily quantifiable at a reasonable cost and must include measures that can be benchmarked against performance of other organizations and service providers.

These are some of the issues that must be kept in mind for achieving a successful outsourcing relationship. However, it is possible for problems to arise in the relationship both due to the customer and the outsourcer. The following section highlights the problems that can turn the relationship sour.

3.2.3 Downside of Outsourcing

The history of long-term outsourcing has not always been glorious. There are many outsourced customers who experience problems over the life of the outsourced relationship. These problems range from data control issues, inflexibility with changing business needs, poor communication, over dependence on the outsourcer, internal resistance to competition between outsourcers. Below is a description of some of these problems and why they surface.

1. *Data Control Issues:* The first problem that customers may experience with their outsourcing relationship is a great frustration with their ability to access key business data and interpret it. Typical of any outsourcing relationship is the fact that customer depends on operational data controlled by the outsourcer. It is in the outsourcer's best interest to keep that information private since it usually describes the real costs and the actual service levels.

The problem of data control issues becomes particularly acute when the customer is considering meaningful changes to its infrastructure that may go against the interests of the outsourcer. Besides the fear of competition, the outsourcer usually resists providing detailed information to avoid customer interference within the business process.

2. *Inflexibility With Changing Business Needs:* Another control-related issue is the ability of the customer to modify the behavior of the outsourcer. Once the supplier understands what changes are needed to meet a new business challenge, the company needs to be able to modify its infrastructure and the outsourcer's behavior. At this point, the outsourcer is in a relatively strong position to bargain because at this time he is the only person who understands what exactly is required to change the customer's infrastructure. This can easily result in the outsourcer charging high rates even for performing trivial tasks. It is also possible that the changes the customer wants to make may not interest the outsourcer, particularly when they are aimed at reducing costs to meet new challenges.
3. *Poor Communication:* Effective communication is essential in all outsourcing relationships. Proper care must be taken to ensure effective communication between

the customer and the outsourcer. However, meaningful communication at many times is extremely difficult to sustain. Almost always it is the customers who are to blame, because they want to focus their energy and time managing other parts of their business thus completely ignoring the outsourced function. At the same time the outsourcer is focused on its own infrastructure and has its own priorities that are not always consistent with the customer's. If the customer is to fully integrate the outsourcer and its infrastructure into its extended enterprise, the customer and the outsourcer must coordinate standards, policies, and times of work and clearly identify responsibilities.

4. *Increased Dependence on the Outsourcer:* Another characteristic of the outsourcing relationship is that it is quite possible that it may lead to an overdependence of the customer on the outsourcer. This behavior can be attributed to two primary factors. First, it is in the outsourcer's interest to encourage this behavior as it increases both the outsourcer's revenues and profits. Secondly, it is quite natural to extend any relationship where the outsourcer provides easy access to otherwise scarce expertise. This dependency if left uncontrolled may cause a customer to outsource in areas that it did not intend to outsource or to develop a dependency on its outsourcer which provides the outsourcer increased bargaining power when renegotiating the contract.
5. *Internal Resistance:* Another potential problem with outsourcing is the internal resistance that can grow in the customer organization. This problem can easily surface due to the clashes with corporate culture. It can also rise from inadequate performance on the outsourcer's side. This often leads to the outsourced infrastructure slowly reappearing in divisions within the organization. This can have many negative

affects. Firstly, because of no coordination it can lead to problems in interfacing. Secondly, these divisions have a negative effect on the overall productivity and lead to a poor cost performance ratio. This misunderstanding also diverts management attention away from more critical issues.

6. *Competition between Outsourcers:* Multiple outsourcing relationships are common within most organizations. Often, these outsourcers see the other outsourcing companies as competition for new services or for contract renewals. This is particularly evident when the outsourcers provide similar services. This non-cooperative attitude among the outsourcers negatively affects the overall performance of the enterprise. To prevent this from happening it is very essential to have a proper knowledge of vendor responsibilities and maintain effective communication between all concerned parties.
7. *Inflexibility:* Vendors are always reluctant to invest in new technology because of the high costs involved and therefore tend to produce as much volume as possible with the existing infrastructure, thereby limiting the flexibility of the process. However, when the outsourcer does introduce new technologies, the vendor usually finds itself in a less economically rewarding position and may demand for a higher price from the company for the services being provided that may lead to a conflict between the interests of the customer and the outsourcer.

Although the above outsourcing problems seem intimidating, but there are solutions that can help prevent these “bad situations” from surfacing and provide for a successful outsourcing relationship. The Telemanufacturing concept can provide a good alternative to avoid the problems arising from outsourcing. It can make companies flexible and more

efficient and help them gain access to world class technologies and ensure a better control and coordination between the customer and the vendor. By using the latest information technology resources and the world-wide-web, Telemufacturing can perform in real time many of the essential functions that can help companies gain competitive advantage and increase their market share. The following section provides solutions to the above outsourcing problems.

3.2.4 Solutions for Outsourcing Problems

- 1. Developing Relationships:* Developing strong relationships between the outsourcer and the customer is essential. The customer and the outsourcer must develop relationships at multiple levels throughout the organization to gain trust and understanding required for long-term relationships. It is important that the senior management of both the organizations is acquainted with one another.
- 2. Coordination:* It is often seen that coordination determines the value of an outsourcing relationship. To ensure successful coordination between the customer and the outsourcer, both parties should coordinate standards such as procurement, shipping schedules, warehousing processes, inventory, and lead-time. When proper care is paid to these standards, then both the customer and the outsourcer can avoid unnecessary costs and enhance the value of the relationship. This coordination can further be improved by having joint budgeting exercises such as cost plans. The customer needs to understand the key cost driver information in the outsourcer's infrastructure and vice versa. Both parties should meet on a regular basis to participate in strategic planning of their respective partners. This is particularly

important when the outsourced relationship is a significant component of the business plan.

3. *Length of the Contract:* Usually it is in the interest of the customer to negotiate a short-term contract which provides a measure of flexibility and price deflation when the contract is re-negotiated. On the other hand it is in outsourcers favor to extend the length of the contract. Whatever the length of the contract, the customer should provide itself a reasonable and a convenient exit in case the relationship becomes unmanageable. The key point to remember when entering into a relationship is that terminating a contract is the worst condition that can occur. The contract must clearly define the potential irregularities that may occur in the relationship so that terminating the contract is not an issue when minor problems surface.
4. *Accountability:* The key to any outsourcing relationship is to remember that “if you can’t measure it, it won’t get done”. Therefore, it is very necessary to have detailed service level standards to measure the actual performance of the outsourcer and the gain to the customer. Outsourcing relationships should allow for the addition of service levels during the term of the contract to take care of changing business needs and service levels. However, a lot of work is required to identify and document these lines of accountability and this is rarely done before the contracts are signed. To ensure proper accountability of performance levels it is highly recommended to carefully consider the contract before agreeing to it and the involved parties need to define the relationship that clarifies the boundaries on quantifiable terms.
5. *Control:* Control or lack of control is a major factor within the outsourcing relationship. It is critical for the customer to have access to detailed information

associated with services provided by the outsourcer and must include an understanding of the key cost drivers critical to the outsourcer's organization. In addition to the cost information, there needs to be qualitative information associated with the reliability and performance of the outsourced services. Influence must be executed through penalties and proper performance standards as was discussed in accountability section. By carefully controlling the outsourcer's ability to expand its relationship, the customer can encourage the outsourcer to negotiate favorably in other key areas, but by not controlling this ability, the customer will give up a substantial advantage.

6. *A Single Point of Contact:* Another area of control is the importance for a single point of contact. A consistent point of contact that coordinates the customer with the outsourcer throughout its business is essential. This single point of contact should be a long-term commitment with adequate resources provided.
7. *Benchmarking:* Benchmarking can be a very useful tool in maintaining an outsourcing relationship. It can be used both for cost and qualitative measurement of performance. In a typical benchmarking situation an outsourcer will agree to measure its cost structure against other outsourcing situations.
8. *Multiple Outsourcers:* If the company has multiple outsourcers in its infrastructure and these outsourcers interface with each other, then the level of management control required increases to ensure proper functioning of the enterprise. Efforts must be made to enable effective cooperation between outsourcers.
9. *Aligning Business Processes:* It is very useful for the parties involved in an outsourcing relationship to ensure that the costs for the outsourcing infrastructure are

allocated back to the business by the business process. This helps the key departments to understand the consequences of using the outsourced services. It also helps the outsourcer understand the implications of its cost and services to the customer's business. When this close alignment is established, the outsourcing relationship is more easily managed allowing key business issues to emerge while avoiding petty conflicts.

By carefully considering the above factors, it is possible to control the outsourcing problems mentioned earlier. A strong relationship between the outsourcer and the customer is very critical for the sourcing arrangement to be beneficial for both the concerned parties. Outsourcing therefore needs to be executed in a proper manner if it is to prove as a valuable strategy for gaining competitive advantage.

CHAPTER 4

TELEMANUFACTURING DSS FOR ELECTRONIC OUTSOURCING DECISIONS

4.1 Capital Investment Strategies

The increasing competition in today's environment is forcing companies to consider electronic outsourcing decisions more often. Large manufacturers are continuously reevaluating the fact whether to produce a part or a service in house or to Telemanufacture it using the state-of-art technology available with an outside source. It is very important that a company addresses this issue carefully since it can have a significant impact on its ability to achieve competitive advantage and profitability. This decision can help a company realize its core competencies, the speed with which it can deliver new products, the productivity of the employees and the operating and capital costs. In this scenario the small and medium size enterprises (SMEs) that specialize in producing well-defined types of products stand a very good chance to become world class competitors. Major corporations are continuously on the lookout for small and medium size enterprises providing specialized services, to be a part of their supply chain, and invest in the latest production technologies and develop ways to improve performance. It is highly desirable therefore to economically justify all capital investments an enterprise makes. New project investments require a substantial investment from the company with high uncertainties with no immediate payoffs associated with them that make it all the more difficult to economically justify the investment made. However, in most cases the main intention behind making an investment is to create future investment opportunities that can guarantee continued

benefits. According to Morris et al, R&D projects should be viewed as a series of sequential decisions involving an R&D phase and a commercialization phase with different risks and uncertainties ³². Companies must consider capital investment decisions carefully, combining properly the knowledge of business with an appropriate financial analysis procedure. Several studies have examined the corporate capital investment, project evaluation and risk analysis practices of large US manufacturing companies ^{33,35,37}. Each of the study suggested the following general conclusions (Refer Table 4.1).

1. Discounted cash flow measures are the most popular primary evaluation measures.
2. Few companies employ quantitative risk assessment and those that do favor sensitivity analysis.
3. Raising the required rate of return is the most popular method for making a quantitative risk adjustment.

Table 4.1 Survey results of capital investment practices among US firms ³⁸

	Klammer	Gitman and Forrester	Kim and Farragher	Klammer, Boch and Wilner
Survey Year	1969	1977	1979	1988
Number of Companies Surveyed	369	268	1000	468
Number of Respondents	184	110	200	100
Response Rate (%)	49.9	41.0	20.0	21.4
	% Using			
Primary Evaluation Techniques:				
Discounted Cash Flow	57	74	68	86
Accounting ROI	26	28	8	4
Payback	12	10	12	5
Risk Analysis Techniques:				
Monte Carlo Simulation	13		10	12
Sensitivity Analysis			23	57
Measuring Covariance of project	3			1
Risk Adjustment Techniques:				
Raising required ROR	21	44	19	40
Shortening payback period	10	13	14	19
Certainty Equivalents		27	3	

The decision model developed here is based on the engineering economy studies and is intended to enable companies to justify their decisions for purchase or in house production. The proceeding sections deal with the working of the software, the formulations used and the capabilities that this software possesses. A small paragraph to explain the concept of core competency has been included.

Core Competencies: Core competencies are the activities that a company performs better than any other enterprise and at ‘best in region’ levels. According to Quinn et al, developing best-in-region capabilities is crucial in designing a core competency strategy. Core values require no external justification; they have intrinsic value and importance to those inside the organization ³⁹.

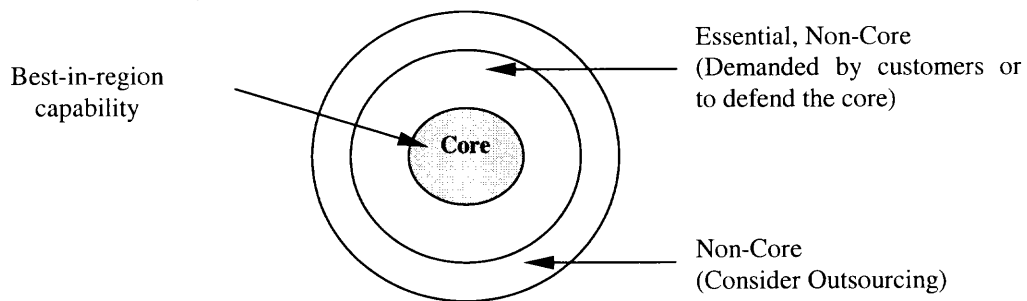


Figure 4.1 Core and Non-Core Competencies

Unless the company is best in region at an activity, it is someone else’s core competency and company will loose a competitive edge by not outsourcing it. Only a few values can be truly core and so fundamental and deeply held that they will change seldom. These core values guide the business decisions and day to day operations of a company.

4.2 Decision Software

Before considering any outsourcing decision, the most obvious question to consider is whether appropriate software exists. A good software offers features required to meet the

needs of an organization, and also be capable of running on IT platforms. As a part of the thesis an Electronic Outsourcing DSS software has been developed using JavaScript and Html for the web version and Visual Basic 5.0 for the desktop usage. This analytical tool considers tangible factors, such as production units, costs, times, etc, as well as intangible factors such as motivation levels, leadership style, etc, for ensuring that the decision a company takes regarding its sourcing policies meets all specific criteria like economic, social, and qualitative. The decision model offers a user-friendly environment for easy decision making.

4.2.1 Capabilities of the Decision Model

The electronic outsourcing decision model provides a user-friendly environment while considering the issue of whether to Telemanufacture or not and makes decision making convenient. It helps to reduce the time spent in making complex calculations and understanding the methodology involved and at the same time ensures proper accuracy. It helps users to make better decisions with better results in a short time. This decision tool is intended for companies that are considering the issue of outsourcing as well as those that are considering a new capital investment. It helps to determine the feasibility of the project or the capital investment being considered. Users will have the choice to evaluate various options at the same time and select the most suitable one. By checking the various permutations and combinations, users can study the sensitivity of the project proposal and identify a suitable vendor or capital investment proposal to justify cost and technological considerations.

4.2.2 Decision Modules

The software incorporates in itself two modules as shown in figure 4.2. The first module (A) is for users who are considering starting a new project or making a new investment. This module makes use of engineering economy studies and helps in the evaluation of alternative capital investment proposals in engineering and business projects.

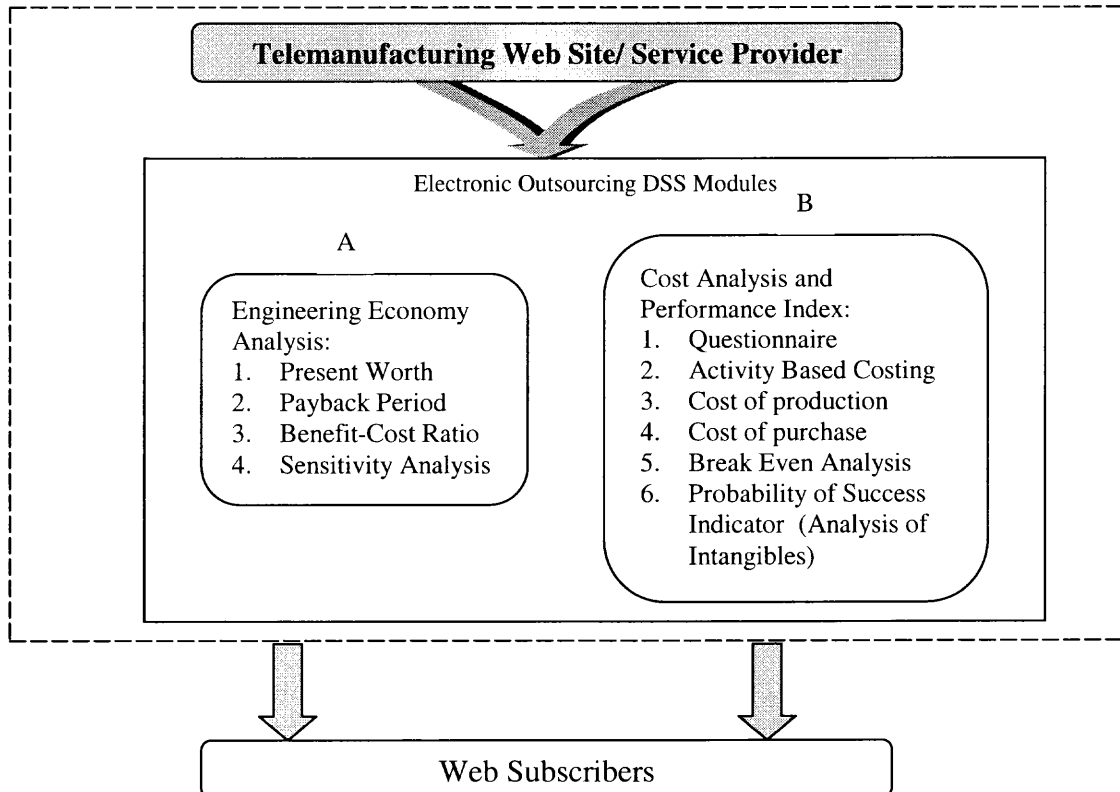


Figure 4.2 Modules of Electronic Outsourcing Decision Model

Capital in the form of money for machines, materials, and people is an economic necessity for all business proposals and companies are increasingly concerned that the available capital be used effectively. For every project there is more than one way in which it can be executed. Engineering economy studies provide a convenient way to deal with the differences in economics results from alternatives. They can help determine whether capital should be invested in a project or whether it should be utilized in a

different manner. Economy studies therefore provide information upon which investment decisions about future operations can be based.

The second module (B) is for companies or users who want to judge whether it will be feasible to produce in-house or to Telemanufacture operations using an external service provider who can do it more effectively and more economically. This module will serve those users who are already in the manufacturing or production process and are on the lookout for cheaper option. By using this module they will be able to realize the costs associated with in-house production as well as the cost of purchase from outside. They will also be able to evaluate some intangible factors that may be critical to the working of the outside vendor as well as the in-house staff. The two modules are dealt in greater detail in the next two sections. Also included in this chapter are two case studies, one for each of the two available modules.

4.2.3 The Decision Making Process - Module A

A fundamental way to solving an economic problem is to base decisions on accumulated knowledge of the past to identify a suitable course of action. Problems in engineering economy originate in the real world of economic planning, management and control (See figure 4.3). They are clarified and better understood by the data from the real world. This information is then combined with the scientific principles to formulate a hypothesis. By manipulating and experimenting with the information gathered from the real world, one can simulate alternative proposals that other wise would be too costly to investigate. This results in a prediction that is used in the real world for its verification. If this prediction is

true then the problem will be solved otherwise the cycle will be repeated with additional information.

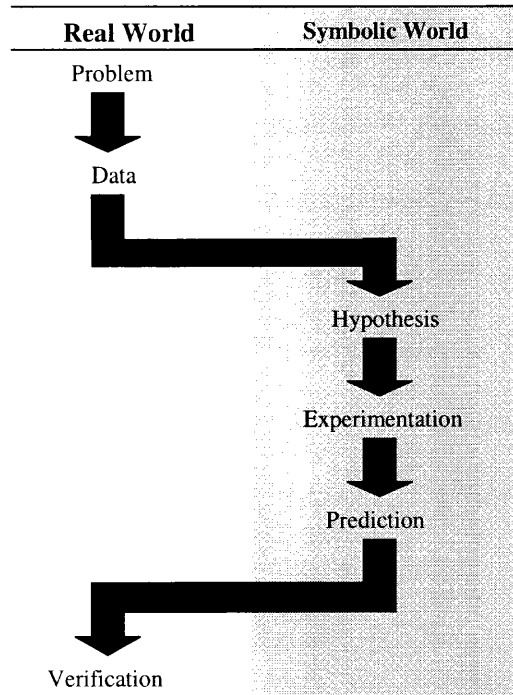


Figure 4.3 Problem Solving Process

The final decision to the problem is based on data from past performances and establishes a course of action that will result in some future outcomes.

The module proposed here, evaluates alternative investment proposals using the engineering economy studies and bases the final decision using the following four criteria.

1. *Present Worth Method*: This method for economy studies is based on the concept of equivalent worth of all cash flows relative to some beginning point in time called the present. All cash inflows and outflows are discounted back at an interest rate. The present cost of the project is calculated by considering the present worth of all future cash flows and also the initial investment to be made at the inception of the project.

Mathematically stated,

$$\text{Present Worth (PW)} = A[(1 + i)^N - 1] / i$$

where, I is the interest rate per interest period; N is the number of compounding periods; PW is the equivalent worth of one or more cash flows at a relative point in time called the present; A is the end-of-period cash flows in a uniform series continuing for a specified number of periods.

The criterion for this method is that as long as the net present worth i.e. the present value of cash inflow minus the present value of cash outflow is greater than or equal (\geq) to zero (0), the project is deemed to be economically executable. However, if this value comes out to be negative, then it is highly recommended to abort the proposal and make necessary changes to the investment proposal to make it profitable.

2. *Payback Period:* Payback period is the time required for a firm to recover its original investment. This method also called the Payout method avoids the need to calculate the cost of capital and uses a cutoff criteria requiring proposals to return their original investment from the savings they generate in a specified period of time. The formula used for this method is,

$$\text{Payback Period} = \frac{\text{Original Investment}}{\text{Annual Cash Flow}}$$

The original investment is the initial cash outlay that the company makes to acquire resources required to start a particular project. The annual cash flow is the difference between the annual cash inflow and the annual cash outflow. The data values used for this formula are not discounted cash flow amounts and also the salvage value for the project is not included.

3. *Benefit-Cost Ratio*: The benefit-cost ratio is defined as the ratio of the equivalent worth of benefits to the equivalent worth of costs. The equivalent worths that are normally considered are Present Worths, Annual Worths or the Future Worths. This ratio is also sometimes referred to as the savings-investment ratio (SIR) by some governmental agencies ⁴². In mathematical terms, the benefit-cost ratio is given by:

$$\begin{aligned} B/C &= \text{present worth of benefits/ present worth of costs} \\ &= \text{equivalent annual benefits/ equivalent annual costs} \end{aligned}$$

For a project to be economically justifiable, its benefit-cost ratio should be greater than or equal to (\geq) 1.0. If more than one project is involved, then the project with the higher B/C ratio should be selected.

The application of the Benefit-Cost ratio has a vast application and is discussed in the greater detail in the book titled *Guidelines for Project Evaluation* ⁴³.

4. *Sensitivity Analysis*: A sensitivity analysis is carried out to determine how a problem will behave under different conditions. According to DeGarmo et al, “ sensitivity means the relative magnitude of change in the measure of merit (such as rate of return) caused by one or more changes in estimated elements or variables” ⁴⁴. In most engineering economy studies, future cash flows are estimated and it is really worthwhile to examine how the worth of a project varies when these estimates are changed. This is very helpful when there is more than a single way of achieving the necessary results. In economic studies, sensitivity analysis can help determine that critical point at which an analysis factor causes an economic proposal to change from acceptable to not acceptable. This analysis is considered during the evaluation of alternative proposals to determine areas for further improvement. The decision model

developed here allows user to analyze three proposals at a time and see how the problem behaves under different sets of constraints. The results of the analysis of the alternative proposals are summarized to enable easy decision making.

4.2.4 The Decision Making Process – Module B

This module is most suitable for companies or users who are considering the issue of outsourcing.

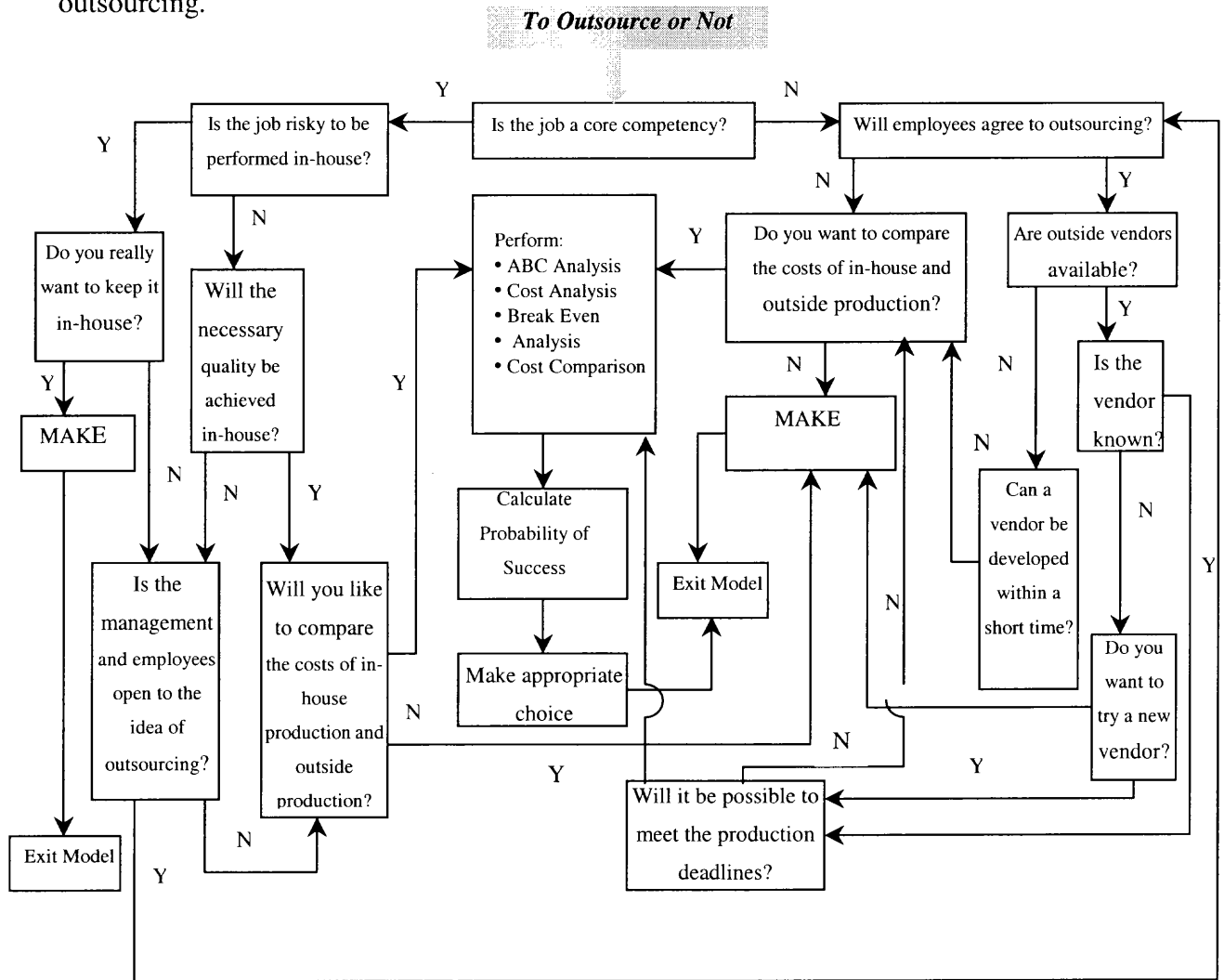


Figure 4.4 Flowchart for Telemanufacturing Decisions

As shown earlier in figure 4.2, this module enables users to evaluate costs associated with production as well as with purchase. It also provides the breakeven analysis and the activity based costing procedures. The flowchart for this module is shown in the figure 4.4.

Companies carry out cost analysis of their production activities or processes to determine the selling price for their product. The various costs that determine the selling price for the product are categorized in figure 4.5. The costs that remain constant irrespective of the level of activity or production are known as the *fixed costs*. These costs are incurred all the time the company remains in business. Typical examples of these costs include rents for land, depreciation on machinery, and interest paid to the banks.

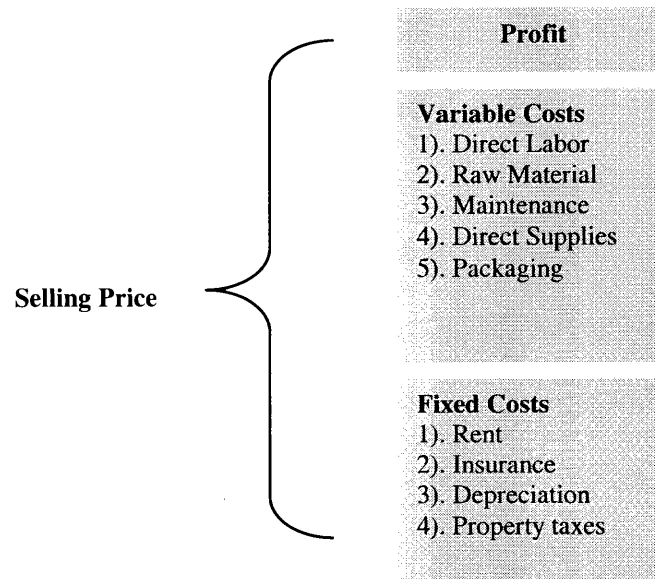


Figure 4.5 Unit Costs

The costs that are proportional to the output, i.e. they increase with the increase in the level of production, are called *variable costs*. These costs are directly related to the product being made and include costs for direct labor, raw material purchased, product packaging costs and maintenance costs.

The module for Outsourcing decisions starts with an initial questionnaire where the users are faced with a set of questions. This is followed by cost analysis procedures to determine the costs of production and purchase. The section also includes Activity Based Costing to determine the unit cost of a product and a Breakeven Analysis for the cost-volume relationship. A performance index to determine the probability of success of the investment follows the cost analysis procedures.

The various procedures available with this module have been addressed below.

1. *Questionnaire:* The module for the Outsourcing decisions starts with a set of questions to judge how interested the user or the company is in outsourcing its activities. The questions vary from the union's agreement to the outsourcing decision to the management's ability to meet production deadlines and acceptable quality levels. Based on the answers provided to the questions, the user is provided with a final decision or is asked to continue with the economic analysis.
2. *Activity Based Costing:* The Module B of the DSS makes use of the Activity Based Costing System to determine the unit cost of production. This method calculates the cost by first tracing costs to activities and then to the final products. Figure 4.6 shows how activity based costing works. It makes use of both unit-based as well as the nonunit-based activity drivers.

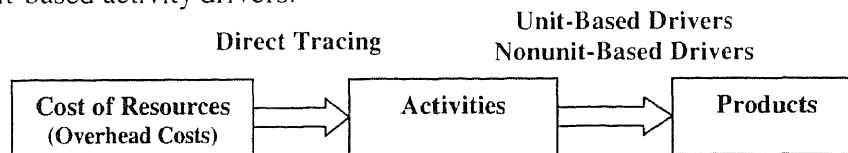


Figure 4.6 Activity Based Costing Procedure

Unit based activity drivers are factors that cause changes in cost as the number of units produced change, for e.g. direct labor hours, machine hours or material costs.

On the other hand, nonunit-based activity drivers are factors, like setup costs, material handling costs, which measure the demands that the product places on activities. The first phase of the ABC analysis involves identifying the various costs associated with the production process and determining the activity driver associated with the activity. To reduce the number of overhead rates, activities are grouped together in sets based on some similarities like a logical relationship among them. Costs are then calculated for the group by summing the costs of the individual activities of the group. The overhead cost calculated for the group is called the homogeneous cost pool. A pool rate for the group is calculated by dividing the cost pool by the activity driver's practical capacity. The overhead costs are traced to the final products by using the pool rates and measuring the amount of resources consumed by each product. Mathematically, this is stated as below,

$$\text{Applied overhead (to a product)} = \text{Pool rate} \times \text{Activity Usage}$$

A case study will be considered later in this chapter to show the application of this analysis.

3. *Cost of Production:* The Electronic Outsourcing DSS enables the user to calculate the cost of in-house production so as to help compare costs of production and purchase.

The cost to manufacture is given by the following formula ⁴⁵.

$$\text{Cost} = C \times D + \sqrt{(1 - D/P) \times (2 \times A \times D \times i \times C)}$$

where, C : Unit Variable cost of Production

P: Production rate in number of units

D: Demand rate in number of units (based on customer's demand and forecasts)

A: Fixed cost of order replenishment

i: Inventory carrying cost (cost of carrying one unit of stock for one year)

4. *Cost of Purchase:* In order to compare the cost of in-house production with the cost of an outside vendor, the model calculates the cost of purchase using the following formula.

$$\text{Cost} = C \times D + \sqrt{2 \times A \times D \times i \times C}$$

The comparison is carried out on the assumption that the machines and equipment available in-house do not remain idle for the time the production activity is outsourced. In case the equipment becomes idle after outsourcing then cost of depreciation of the machinery should be added for calculating the cost of purchase.

Mathematically, the Cost of Purchase in such a case will be:

$$\text{Cost} = C \times D + \sqrt{2 \times A \times D \times i \times C} + \text{Depreciation on Machinery}$$

5. *Break Even Analysis:* Break even analysis is used to study the effects of the variations in the fixed and variable costs on the profitability of a business. It helps in determining the volume or level at which revenue and total cost of operations exactly breakeven, i.e. the business is neither making money and nor is it losing any.

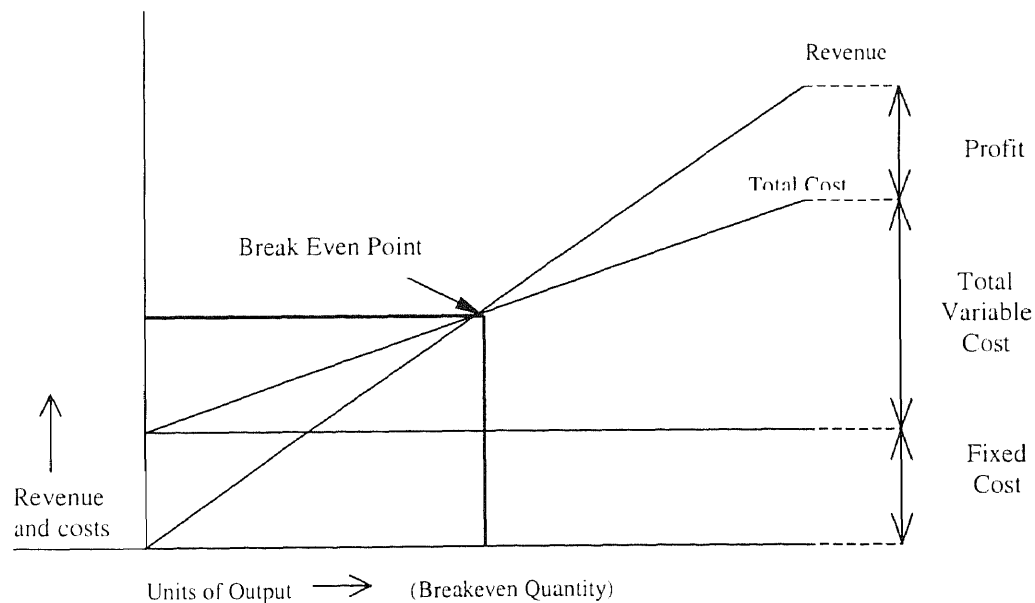


Figure 4.7 Break Even Chart

The alternative with a lower quantity or volume to breakeven can ensure faster profitability for the manufacturer. In a breakeven chart (figure 4.7), the vertical scale refers to the revenue and costs incurred by the company and on the horizontal scale, the volume or the quantity is depicted. The break-even point occurs where the total costs incurred becomes equal to the total revenues generated. At this point the manufacturing process is at break even and there is no loss or profit. The volume or the quantity that corresponds to the breakeven point on the chart is termed as the breakeven quantity. Mathematically, a break even point is given by:

$$\text{Break Even Quantity} = \text{Fixed Costs} / \text{Unit Contribution margin}$$

The contribution margin is determined by subtracting the variable cost per unit from the unit sale price of the product. The Electronic Outsourcing decision model helps to evaluate alternative proposals for break even quantity analysis and suggests the one that can break even quickly and enable quicker profits for the company.

6. *Probability of Success Indicator*: The probability of success indicator or the PSI is a number lying in the range of 0-100, that is assigned to projects using a scoring system and in turn gives a measure of how likely is the project to complete successfully. The PSI can be calculated whenever it is felt appropriate in a project's life.

Table 4.2 Scoring System for PSI Calculation

Step	Score	Totals
1	20	
2	20	
3	10	
4	10	
5	10	total=70
6	10	
7	10	
8	10	total=30

The final decision is based on a number of factors, including intangibles like leadership styles, awareness of what's going on, and the motivation and dedication level of the work force. This process can be carried out by an individual such as the project manager or also by all of the people involved in the project and their scores averaged. The Electronic Outsourcing DSS provides a convenient way to carry out this analysis and is available in the outsourcing module of the decision tool. The following paragraphs explain how this method is applied and the factors considered for it. (For more information on the PSI methodology, refer "How to run successful Projects II, the Silver Bullet", by Fergus O' Connell.)

PSI Calculation: The PSI is calculated by applying a score to each of the steps (factors) using the scoring scheme shown in Table 4.2. The scores are assigned to the factor (figure 4.8) based on the how strongly that factor has been implemented and considered in the execution of the project.


PSI	
Make or Buy Decision Tool	
Steps:	
The factors considered for the analysis are listed below. The numbers in square brackets show the maximum allowable score for that factor.	
1. Goal [20]	Goal clearly defined? Is there enough commitment towards the job?
2. Well Defined Tasklist[20]	Is there a clear understanding of the tasks related to the job under consideration?
3. Leadership [10]	Is there a person who has the 'fire in the belly' to get the project done?
4. Assign People [10]	Will the right people be assigned to the jobs?
5. Margin for error [10]	Consider the major risks involved. How strong is the fallback position? Whats the possibility of achieving the final goal in case of a 'collapse'?
6. Management Style [10]	Comment on the mangement style and to what extent will it contribute to the success of the project?
7. Know what's going on [10]	Analyze the reporting and monitoring mechanisms in use. Low score for no monitoring and controlling
8. Communication [10]	Comment on the communication and coordination among the employees. Difficult to judge for an outside vendor but the decision can be based on past experiences if any.
Continue	Back to Options

Figure 4.8 Intangibles Considered for PSI Analysis

The *factors* that were considered for the analysis are:

Goal: This factor basically evaluates the fact whether the main objective behind a given investment or strategy is clearly defined or not. It measures the commitment of the employees and the management towards a particular objective. Issues that need to be considered for this particular factor include as to whether a proper description for the project exists or not, or whether the key questions, listed below, have been properly addressed or not.

- What will the completion of the project mean to the team as a whole and to each of its member?
- Why do the people want to do the project?
- What are the things the project will actually produce? Where will these things go? Who will use them? How will they be affected by them?
- What would be the best possible outcome of the project?
- What sort of recognition will you achieve from this project?
- Why do you want to do it?
- Do you think it's a difficult task you have taken up?
- Can it fail?

This factor is considered to be quite important in the analysis and is allotted a maximum achievable score of twenty (20).

Job List: This factor is considered to measure the extent to which the people concerned understand the tasks related to a particular job. The effectiveness in this regard is based on the existing condition of the job list, whether it is up to date or whether it is complete. A good job list should cover each and every issue related to

the job concerned. It should also highlight all the objectives of performing the job. This factor is assigned a maximum achievable score of twenty (20) in the scoring scheme.

Leadership Style: A leader can really effect the entire outcome of a project. A person with the correct motivation and dedication and who can really stand out of a group is a big asset for any company. To avoid conflicting views, it is always good to have only one leader who can guide the rest of the group. This factor is assigned a maximum score of ten (10). A score of 10 is allotted when there is a single leader with the necessary leadership skills. In case of more than one leader, scores are reduced because of the confusion that may arise due to multiple leadership.

Assignment of People: An important asset to any project is the manpower or the work force that is assigned to it. The key is to select the right person for the right job. When this criterion is met, it is highly probable that the project will be successful. The roles of the people involved should be clearly laid out so as to avoid any confusion that may arise. The people should also be fully aware of what the management expects of them. This step is rated on a scale of 1-10.

Margin of Error: No project proposal is perfect and might fail leading to heavy losses for the company. To counter this, a fall back alternative must be available, that can take the place of the original proposal and achieve the desired results. All the major risks involved with a project should be thoroughly identified, and actions taken to prevent them from surfacing. The step is given a score between 0 and 10, stronger the chances of achieving the desired results in case of a failure; higher is the allotted score.

Management Style: A strong and intelligent management is critical to the success of a project. The management should be flexible enough to try out different strategies and should have a clearly laid out goal and visualize what strategies it would need to adopt to achieve its objectives. This step is rated on a scale of 0-10.

Knowledge of What's Going On: It is very important to analyze the reporting and monitoring mechanisms available to provide information of the progress of the project. This can help to make sensible decisions and take appropriate actions to control the project to meet its goal. This can be done using a computer based planning tool that can track progress by indicating the jobs done, the costs incurred and the tasks that need to be completed. This step is given a score between 0 and 10.

Communication: There should be proper communication between the management and the employees. The employees should be kept aware of the management goal and how their actions can help in achieving the set targets. They should be kept informed of the progress of the project and should be given equal opportunities to voice their views. The rating scale used for this step is 0-10.

The PSI analysis can be a useful tool for determining the probability of success of a project. It considers various intangible factors such as leadership style, assignment of people, margin of error, extent of communication between the management and the employees to base the final decision. The next section deals with two case studies that have been considered to show the application of some of the features available with the Electronic Outsourcing DSS.

4.3 Case Study I

A company is going to install a new plastic-molding press. Three different presses are available. The essential differences as to initial costs, revenues and operating expenses are as follows:

Table 4.3 Cost Data for Case Study I

	Press		
	A	B	C
Initial Investment	\$11,000	\$13,600	\$20,400
Economic Life	5 years	5 years	5 years
Salvage Value	\$6,000	\$6,500	\$11,000
Annual Revenues/Savings	\$13,500	\$14,500	\$15,000
Annual Disbursements			
Power	\$880	\$880	\$2000
Labor	\$11,000	\$10,500	\$8000
Maintenance	\$700	\$750	\$925
Property taxes and insurance	\$240	\$262	\$410
Total Annual Disbursements	\$12,820	\$12,392	\$11,335

Each press will produce the same number of units. However, because of different degrees of mechanization, some require different amounts and classes of labor and maintenance costs. Respective salvage values are indicated in the table. Any capital invested is expected to earn at least 10% before taxes. Which press should be chosen?

4.3.1 Evaluation of Case – I:

The first module of the Electronic Outsourcing DSS uses engineering economy studies to evaluate alternative investment proposals for selecting the best proposal among the choices available. The main screen of this module in Visual Basic version

looks like the one shown in figure 4.9. On clicking Proposal I, the user will have to enter all the details related to proposal I.

Life Cycle Cost

Make or Buy Decision Tool

Life Cycle Costing

In the Acquisition of a facility, if the level of performance or effectiveness is fixed, the decision becomes one of finding an alternative among the mutually exclusive proposals that requires the minimum cost.

This model is designed to calculate the Life Cycle Cost of the project, the Benefit-Cost Ratio and the Payback period for the project.

Click here to enter Proposal I details.

What is Life Cycle Cost? What is Benefit-Cost Ratio? What is Payback Period?

Evaluation of Alternative Proposals

Proposal I Proposal II

Proposal III Summary Sheet

To Start Again: Click Here! and then Start with Proposal I

Back to Main Menu


Shows a summary of the results of all project proposals

Figure 4.9 Main Screen of First Module

Similarly, by clicking on proposals II and III, the user can enter details related to the other alternatives. This form also provides some basic definitions like, life cycle cost, Benefit-Cost Ratio, Payback Period, which might of use to the user. The form that comes up on clicking proposal I is shown in figure 4.10. The user will have to enter values in the appropriate blanks. The form shown here has values taken from proposal I of the case study.

Proposal I

Make or Buy Decision Tool



Proposal I

a). Enter the initial cost of the Project

b). Enter the annual operating and maintenance costs associated with the project

c). Enter the estimated annual benefits

d). Enter the Salvage value. (if none , then enter 0)

e). Enter Minimum Attractive Rate of Return.


f). Enter the estimated life of the Project.

Figure 4.10 First Proposal of Case I

After entering all the values in the appropriate blanks, the continue button on the form will bring up the evaluation results of proposal I. This form shows the present value of all cash outlays, present value of all cash inflows, the present cost of the project, the benefit-cost ratio for the project and the payback period. The evaluation result form for proposal I is shown in figure 4.11.

Evaluation I

Make or Buy Decision Tool



Proposal I - Evaluation

Present Value of Cash Outlays

Present value of Cash Inflows

(A Benefit-Cost Ratio > or = 1 is required for a project to be accepted.)

Figure 4.11 Result Form for Proposal I

These results are also highlighted in the summary sheet. The summary sheet after evaluating the remaining two alternatives also, looks like the one shown in figure 4.12. It allows the user to easily compare the three alternatives and make an appropriate decision.

Summary Sheet

Make or Buy Decision Tool

The results of the analysis of the various alternative proposals have been summarized in the table shown below.

I	59597	54901	4696	0.921204087454066	15
II	60575	59002	1573	0.974032191498143	6
III	63360	63691	-323	1.00509720994024	5

Note: Select the proposal that costs the minimum (Present Cost) and has the highest Benefit-Cost Ratio.

[Back to Start Page](#)

Figure 4.12 Summary Sheet for Case I

Analysis: The summary sheet provides the results of the evaluation of the three alternative proposals. The main criteria is to select the proposal that cost the minimum, i.e. has the minimum present cost and has the highest Benefit-Cost Ratio. As can be seen from the summary sheet, proposal III costs the minimum and also has the highest Benefit-Cost Ratio, making it an appropriate investment proposal. This investment proposal will also be able to pay back its capital investment in a much shorter time period. The best choice therefore will be to select proposal number three. This analysis can also be carried out using the web version of this decision tool. The analysis performed using the web version is shown below in Figure 4.13.

4.4 Case Study II

Goodmark Company has a plant that produces screws. Currently it is considering a make or buy decision to decide whether to continue producing in-house or to outsource the manufacturing activity. In its company there are two producing departments: cutting and

The screenshot shows a web browser window with the title 'New Page 2 - Microsoft Internet Explorer provided by MSN'. The address bar shows 'E:\Wk\ecconomy.html'. The main content area is titled 'Make or Buy Decision Tool' and contains a data entry table and a results table.

	Proposal I	Proposal II	Proposal III
Initial Cost of project:	11000	13500	20400
Annual Operation and Maintenance Cost:	12820	12392	11335
Estimated Annual Benefits:	13500	14500	15000
Salvage Value (0 if none):	6000	6500	11000
Minimum Rate of Return:	10	10	10
Estimated Life of the Project in Years:	5	5	5
<input type="button" value="Calculate Proposal I"/> <input type="button" value="Calculate Proposal II"/> <input type="button" value="Calculate Proposal III"/>			
<input type="button" value="Calculate All Proposals"/> <input type="button" value="Clear All"/>			

Proposal I:	Present Value of Cash Outlays	Present Value of Cash Inflows	Present Cost of project	Benefit Cost Ratio	Payback Period
	59597.886383	54901.149325	4696.7370584	0.9211928921	16.176470586

Figure 4.13 Results for Case I using Web Version of Decision Model

threading. Cutting is responsible for shaping the screws and threading is responsible for making the threads on the screws. The expected product costing data is given in Table 4.4. Four types of overhead activities are assumed: machine setup, moving a batch of screws, supplying electricity and inspection. The setup costs are assigned based on the number production runs handled by each department. Material-handling costs are assigned by the number of moves used by each department. Power costs are assigned in proportion to the machine hours used by each department. Finally, inspection costs are assigned in proportion to the direct hours used.

Table 4.4 Cost Data for Case Study II

Units Produced Per Year	1000000
Demand Per Year	800000
Inventory Carrying Cost	\$.9 per unit
Prime Costs	\$78,000
Direct Labor Hours	35,000
Machine Hours	10,000
Production Runs	300
Number of moves	120
Overhead Costs	
Setup/Order Processing costs	\$72,000
Materials Handling	\$40,000
Power	\$36,000
Inspection	\$14,000

Also, the cost of processing an order is \$240. The company wants to carry out a cost analysis of its production activity to compare its cost with that of an outside vendor. The vendor is offering a per piece price of \$.18. In addition the vendor also estimates that ordering cost per piece will be \$.05. Also the inventory carrying cost per unit for the vendor will be \$.09. Should the company decide to outsource the production of screws?

4.4.1 Evaluation of Case II

The second module of the Electronic Outsourcing DSS is used to analyze this case. This module starts with a set of questions that are basically used to determine how interested the firm is in outsourcing the job under consideration or for evaluating its present infrastructure to see if the job can be done in-house. The user has to answer some questions, like the one shown in figure 4.14, before the necessary analysis procedure can be engaged.

Make or Buy Decision Tool

Question

Do you have outside vendors available with you who can do the job for you?

Yes

No

Back




Figure 4.14 Questionnaire for Preliminary Analysis

After studying the problem, it is somewhat clear that the company is inclined towards outsourcing, and may not face any opposition from the union or employees as regards to their proposal for outsourcing. Also the company has an outside vendor available who can complete the job that is being considered for outsourcing. After preliminary analysis, the module determines an inclination of the company towards outsourcing the production of screws and suggests a comparison between the costs of production and purchase to

determine a cheaper option for the company's business. The Activity Based Costing (ABC) procedure available with this module is used to calculate the unit cost of production, by using the overhead cost data and the other information provided in the case under study. The values pertaining to the production activity are entered in the form shown in figure 4.15.

Activity Based Costing			
Make or Buy Decision Tool		NUT	
Activity Based Costing			
The decision tool uses Activity Based Costing to calculate the unit cost of production. Enter the following data and then continue to the next screen.			
Units Produced Per Year	1000000		
Prime Costs	76000	What are Prime Costs?	
Direct Labor Hours	35000	What are Direct labor hrs?	
Machine Hours	10000		
Number of Production Runs	300	What are Production runs?	
Number of Moves	120	What is a "Move"?	
Machine Setup Costs	72000	Materials Handling Costs	40000
Power Costs	36000	Inspection Costs	14000
Continue	Back	Reset	To Exit Model


Figure 4.15 Activity Based Costing Using Decision Model

The information entered is formulated to calculate the unit cost of in-house production. This cost is then used as input for the cost analysis procedure that follows the Activity

Form20	
Make or Buy Decision Tool	
NUT	
The next stage involves applying the overhead to each product and calculating the unit cost of production.	
	76000
a). Pool - I	112000
b). Pool - II	50000
Total Manufacturing Costs	240000
	1000000
Unit Cost of Production	0.24
Continue	Back

Figure 4.16 Result Form for Activity Based Costing

Based Costing. The results obtained from the ABC analysis are shown in Figure 4.16. The unit cost of production for the analyzed problem comes out to be \$0.24. This cost figure is now used for the yearly cost analysis. The cost analysis is carried out in two stages: first for the in-house activity and second for the vendor. The results of these two analyses have been summarized in the form shown in figure 4.17.

Form15


Make or Buy Decision Tool

Cost Comparison: In-House Vs Outsourcing

Cost of In-House Production is	196293
Cost of Outsourcing is	144000

Analysis:

Cost of outsourcing is less than cost of in-house production. It will be economical to use an outside vendor.

[Back to Options](#)

Figure 4.17 Results of Cost Analysis Using Electronic Outsourcing Decision Model

From figure 4.17, the cost of in-house production comes out to be greater than the cost of outsourcing. Therefore, it will be more economical and justifiable to outsource the production of screws. A break-even analysis available with this module can also be carried out to study the cost-volume relationships and determine which option will achieve a break-even point faster. For users reference a detailed user manual for the decision model has been provided in appendix section, and will be helpful for a clear understanding of the functionality of this Electronic Outsourcing DSS.

CHAPTER 5

TELEMANUFACTURING SERVICE PROVIDER/ WEB SITE

5.1 The Telemanufacturing Service Provider

The Telemanufacturing web site available at www-ec.njit.edu/telemfg/ acts as the main service provider for the users to access the available services like Rapid Prototyping, Electronic Outsourcing DSS, Flexible Manufacturing System design software, etc. The main objective of this web site is to introduce the concept of Telemanufacturing globally and provide users especially the Small and Medium sized enterprises with world class technology and expertise that they might find it difficult to afford. The Overview link on the home page of the web site provides information related to the concept of Telemanufacturing and also provides links to other research centers and institutions providing similar services. Another purpose that this web site is supposed to serve is to act as a testbed to monitor the performance of the Telemanufacturing Infrastructure and receive user feedback for future improvement. All the services are controlled through the Control Center available on the web site and it can be accessed from the home page of the web site by clicking on the Control Center link. By accessing the Control Center, a manufacturer can receive advice from decision support systems on whether to outsource or to manufacture the product in-house, select equipment for a manufacturing cell, and develop a prototype on a Rapid Prototyping machine that can be checked for different conditions of stress and strains before doing the actual production.

This infrastructure is still under development and new services are being added from time to time. Also, the previous experience from using the infrastructure has helped in

identifying problems that may arise in using the various services. Steps are also being taken to increase traffic to the web site. The next few paragraphs highlight the new services that have been added to the web site especially for the small and medium sized enterprises.

5.1.1 Equipment Selection Procedure for Manufacturing Cell Design

The Telemanufacturing web site incorporates a software called the RAMCOSS, a DSS that concurrently considers the selection of Robots and machine centers for the design of a flexible manufacturing system. This DSS developed using Visual Basic and MS Access, evaluates the design and geometry of the mating parts that are to processed and based on the design recommends the machining center and robot combination that can enable maximum cell performance subject to various operational and budget constraints. The DSS basically consists of two components the database and the optimization module. All the information related to the machining centers and robots is maintained in the comprehensive database developed using MS Access 7. The information available with the database includes vendor prices and specifications for the machining centers and robots. The optimization engine is used for performing sensitivity analysis on the possible machining center-robot combinations to give the user the most suitable combination taking into consideration the available budget and the operational parameters. The working of this DSS (figure 5.1) involves a pre-selection phase that eliminates the infeasible alternatives based on some basic criteria like robot payload, reach, etc. The results of this phase can be modified to further suit ones requirements by excluding or adding alternatives that do not exist in the database. The optimization engine

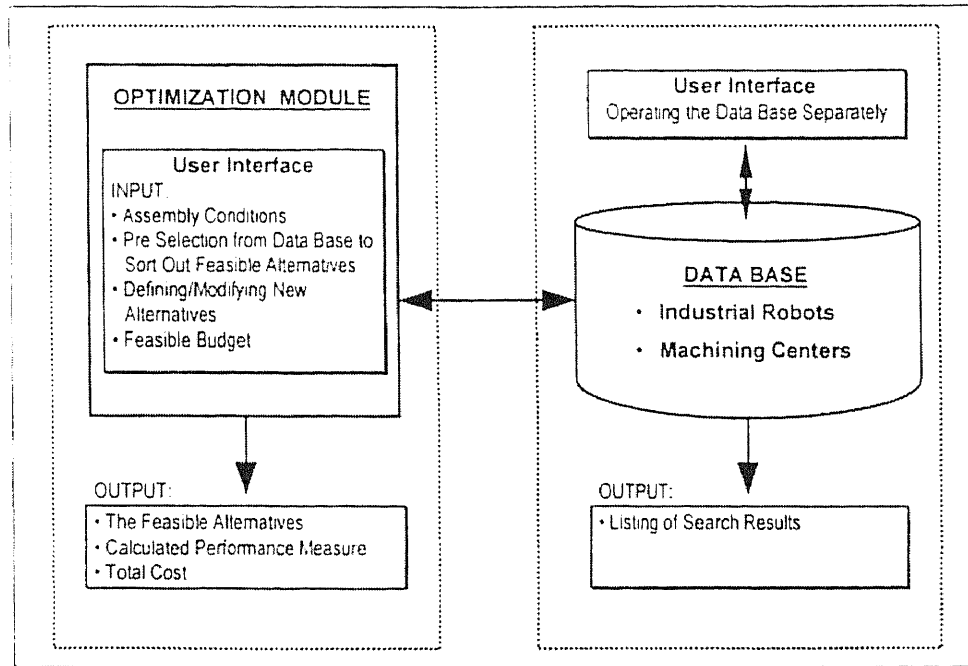


Figure 5.1 Basic DSS Structure

is then used to provide the optimum combination of machining centers and robots that ensure greater efficiency for the manufacturing cell.

The decision software can easily be downloaded from the www-ec.njit.edu/telemfg/ web site. For using this service, the user will be required to download two files, the exe application and the database (figure 5.2). The files available on the web site are zip files and therefore will have to be unzipped first before using. The steps to be followed for using the decision software are provided on the web site. The version presently available is compatible with Windows 95/98 operating systems, but a newer version compatible with Windows NT will be available soon. In some cases user may face problem in using this software. In such a case, they have to download the file GRID32.OCX also available on the web site and save it in the C:Windows/System folder on their computer. This file then has to be registered with the system for the application to run properly. For registering the file, the steps given below will have to be followed.

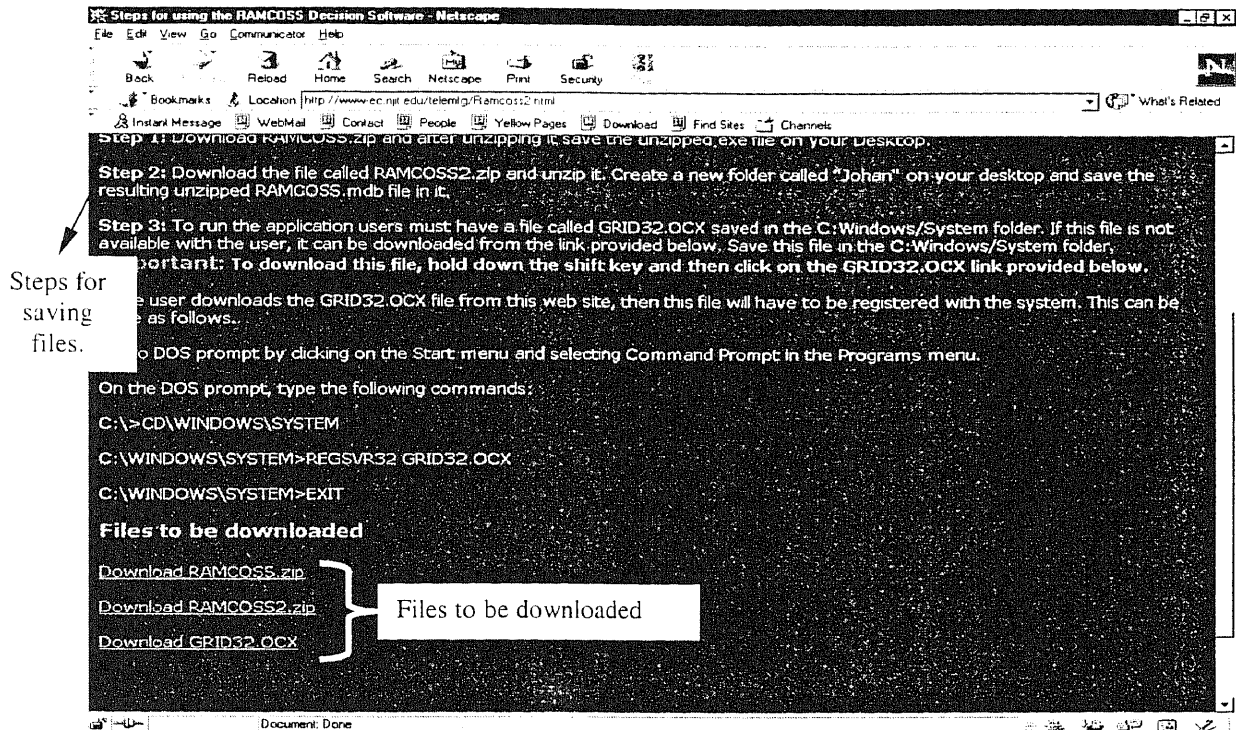


Figure 5.2 RAMCOSS Download Page

On the Dos prompt, type the following commands:

```
C:\>CD\WINDOWS\SYSTEM
```

```
C:\WINDOWS\SYSTEM>REGSVR32 GRID32.OCX
```

```
C:\WINDOWS\SYSTEM>EXIT
```

After registering the GRID32.OCX file the decision model can be used by saving the application file on the desktop and the database in a folder named "Johan" that is created on the desktop.

5.1.2 Evaluation Procedure for Technological Investment Alternatives

An evaluation procedure for the evaluation of alternative technological investment alternatives has been included on the web site. This decision procedure has been developed to help in the selection of an alternative investment proposal from among the various possible choices based on the desired outcomes, intangible factors, and

constraints. The decision process involves identifying business needs, economic requirements, tangibles and constraints and then carrying out a preliminary analysis to identify a set of feasible solutions to meet the requirements. The DSS further evaluates each of the possible solution to justify the economic considerations and makes an appropriate choice among the pre-selected options. The structure of this decision procedure also allows consideration of all effective and efficiency factors that influence the success of a capital investment. The software provides the user with a flexible environment where it can decide on its own the factors that will be most suited to a particular situation. It is relatively easy to use and uses Microsoft Excel as its platform for analyzing the competing investment proposals. A sample blank page for an investment alternative is shown in figure 5.3.

Investment Project ID #	Alternative #1	Evaluation standards	Weight on Decision (1 to 10)	Evaluation how well Solution is expected to meet the specified objectives on range from	Degree of Confidence in Accuracy of Evaluation	Score (Solution Valuation)									
Name				<table border="1"> <tr> <td>Desire Max</td> <td>Normal</td> <td>Average</td> </tr> <tr> <td>1</td> <td>3</td> <td>5</td> </tr> <tr> <td>Min</td> <td>Sustainable Expense</td> <td>0</td> </tr> </table>	Desire Max	Normal	Average	1	3	5	Min	Sustainable Expense	0		
Desire Max	Normal	Average													
1	3	5													
Min	Sustainable Expense	0													
Rate of Return	Payback														
Initial	PW of Cost														
Objectives Desired Outcomes, and Other Factors Influencing Investment Decision															
Technical Requirements															
1															
2															
3															
4															
5															
6															
Economic Requirements															
1															
2															
3															
4															
Constraints															
1															
2															
3															
4															
Others (Intangibles)															
1															
2															
3															
4															
				Total score											
				% Score/Desired Performance											
				% Score/Maximum Possible Performance											
				Cost per Score Point											

Figure 5.3 A Blank Page for Evaluation of an Alternative

5.1.3 Electronic Outsourcing Decision Support System

The Electronic Outsourcing DSS, developed in Visual Basic and JavaScript, will help the users in deciding whether to produce a part or a service in-house or to outsource it. It will also help for evaluating new capital investment proposals. The decision model makes use of engineering economy studies and costing analysis procedures to determine the feasibility of the project or the capital investment being considered. It incorporates two modules and includes analysis procedures for Activity Based Costing, Cost Analysis for Production and Purchase and a break-even analysis procedure. The flowcharts for the modules are shown in figure 4.2 and figure 4.4 in chapter 4. Also included are models for calculating the Present Worth of a project, the Benefit-Cost Ratio, and the Pay Back period. By checking the various permutations and combinations, users can study the sensitivity of the project proposal. The DSS available on the Telemanufacturing web site can be used in two ways. The web version of the model developed using JavaScript and html enables the use of the DSS directly in the browser. The second option allows the software to be downloaded from the web site, which then can be used on ones desktop. The desktop version is an exe file developed using Visual Basic 5.0. A user manual for the software is included in the appendix section.

The Telemanufacturing web site therefore provides an Internet based manufacturing and process planning service that can be accessed globally and can help to improve the technological capabilities of particularly the small and medium sized enterprises. The various specialized expert centers (SECs) available with the service provider incorporate state-of-art in their respective fields that can enhance the flexibility and efficiency of the subscribing enterprises.

CHAPTER 6

SUMMARY AND FUTURE RESEARCH AREAS

6.1 Summary

The World Wide Web has opened new avenues for virtual manufacturing. Telemanufacturing or manufacturing using the Internet is increasingly being considered by companies to save costs and gain competitive advantage. In this work a decision model has been integrated into the Telemanufacturing service provider available at NJIT to help companies determine their outsourcing policies electronically and decide whether to produce a service or a part in-house or to Telemanufacture it. The development of the Electronic Outsourcing DSS has been motivated by the wide spread use of Outsourcing for companies to achieve critical improvements in success factors like quality, productivity and time to market. The DSS incorporates certain costing and break-even analysis procedures for performing first cut economic analysis on in-house and outsourced production activity to aid users in Telemanufacturing decisions. The model also uses engineering economy evaluation procedures for comparison of alternative capital investment proposals. Further the compatibility of the decision model with the World Wide Web will allow real time decision making. In addition to the development of the Electronic Outsourcing DSS, several of the existing modules of the Telemanufacturing enterprise have also been refined. A DSS for Equipment Selection for Manufacturing Cell Design called the RAMCOSS has been integrated with the service provider web site and will be useful for companies in developing flexible manufacturing cells. This DSS selects pairs of robots and machining centers concurrently using certain algorithms that maximize the overall performance of the manufacturing cell. It mainly

consists of two components, the database and the optimization engine. The database includes information about the machining centers and robots and the optimization engine is used to optimize the overall manufacturing cell performance. This DSS can be used for assembly of parts that have a simple geometry i.e. a peg-in-a-hole type and as well as for parts wherein the angular displacement or angular repeatability of the assembly device can affect the outcome of the process.

6.2 Future Work

Some of the key areas that need to be addressed to make the Telemanufacturing enterprise function as a complete service provider are listed below.

1. *Rapid Prototyping*: The rapid prototyping facility, that uses resin polymer to develop prototypes of parts to check for different conditions of stress and strains before doing the actual production, can be linked with the Telemanufacturing enterprise to enable users to submit their designs of parts over the Internet. The issues to be taken care of in this regard are:
 - a) System Configuration: A Windows NT 4.0 workstation can be used for the transfer of part designs to the prototyping machine. The Stereolithography machine supports commonly used CAD softwares like Pro/Engineer and SDRC Ideas. However, Pro/Engineer software incorporates greater solid modeling and design analysis capability, so will be a better choice. The configuration that will be required to run this workstation is shown in Table 6.1.
 - b) Internet submission of parts: An infrastructure can be developed that can allow users to submit .stl files made using commercially available softwares like Pro/Engineer

and SDRC Ideas directly over the Internet. Also the system should be able to verify that the request to prototype a part has come from a computer that has been enabled to make such a request and should also acknowledge it with a return email message.

- c) Prototyping Errors: The designs sent using the Internet may develop some errors during transfer and therefore it is important to further improve the .stl file checker, ADMesh to correct all errors automatically.

Table 6.1 Configuration for Windows NT Workstation

Characteristic	Configuration Required
Processor	Pentium, Pentium Pro, Pentium II, Xeon, and Pentium III
RAM	128 MB
Memory	1500 MB
Graphics Hardware	S3 Compatible Graphics
Network	Microsoft TCP/IP or Ethernet Network Adapter
File System	HPFS, NTFS file system
Mouse	Microsoft approved 3-button mouse
Monitor	Minimum 1024 x 768 resolution and 256 colors.

2. *RAMCOSS*: The equipment selection model developed for Flexible manufacturing Cell design, has been made using Visual Basic and MS Access. This application cannot be opened directly in the browser and has to be downloaded as a file, thereby giving easy access to all the information that is available with it. By writing the whole application using a scripting language like JavaScript, VB Script or Active server Pages (ASP), this application can directly be accessed over the Internet and the information can be secured using a possible login-password option. Additionally, the DSS can be further developed to enable direct search from equipment manufacturers.
3. *Data Transfer and Retrieval*: Some critical factors that affect transfer and retrieval of data over networks like the Internet is the Internet Bandwidth and the network

firewalls. Internet bandwidth is a measure of the data transfer rate and depends on modem speed. The minimum Internet bandwidth required for transferring video and audio must be at least 50kbps. This is important for downloading and transferring CAD designs. The firewalls also tend to restrict the speed of data transfer across the networks. A firewall is a security software that acts as a guard between two or more networks. It protects the organization network against hackers, but also at the same time slows down the network connection. They are of two types: Filtering Firewall and Proxy Firewall. A proxy firewall has been found by many organizations to be more efficient in protecting the network and at the same time ensuring faster performance. The Telemanufacturing enterprise will also need a proper combination of Internet Bandwidth and Firewalls to become an efficient service provider.

4. *Telemanufacturing Capabilities:* The scope of the Telemanufacturing enterprise can be further expanded by introducing new services such as CAD design facility or a CNC machining capability to the list of available services.

6.2.1 Conclusion

The scope for further improvement of the Telemanufacturing facility is enormous. In its present form it functions as an effective service provider, and particularly be of great use to small and medium sized enterprises. The Electronic Outsourcing decision model developed here has helped to further expand the scope of the Telemanufacturing web site, the actual service provider, and will make outsourcing and new capital investment decision making easier and less tedious.

APPENDIX A

USER MANUAL FOR ELECTRONIC OUTSOURCING DSS

The Electronic Outsourcing decision software incorporates two modules, one for those who are starting a new business and want to evaluate various alternative investment proposals and the second for those who are already in business and are considering the issue of outsourcing to achieve cost and efficiency improvements. The decision software is available on the www-ec.njit.edu/telemfg/ web site from where it can be downloaded on to a computer desktop. The model is in the form of a zip file (makeorbuy.zip) that can easily be unzipped and used. This user manual will provide important information of how to use the software.

1. *Downloading the Decision Software:* Using Microsoft Internet Explorer or Netscape Navigator go to the Telemufacturing homepage at www-ec.njit.edu/telemfg/. Click on Control Center (See Figure A.1)

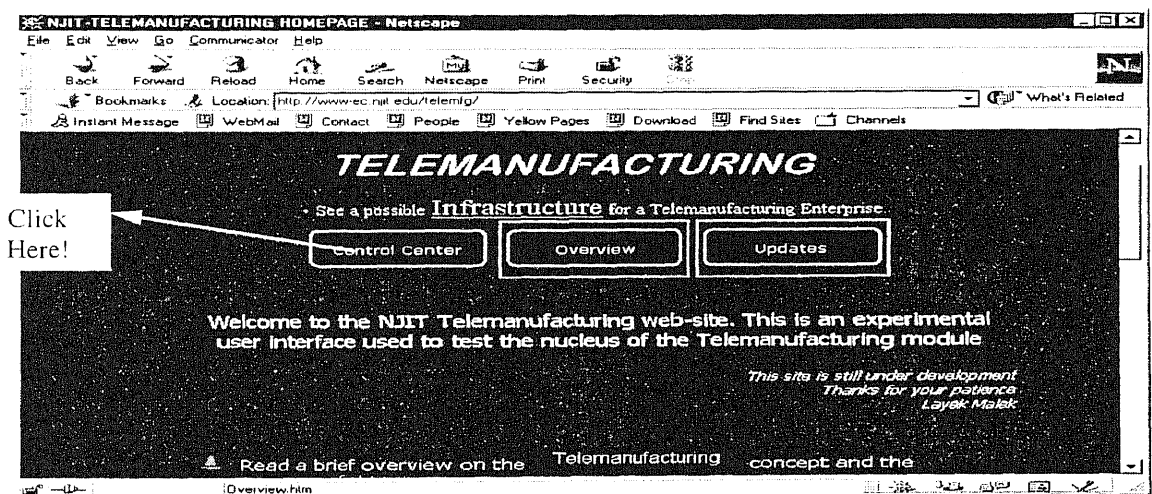


Figure A.1 NJIT Telemufacturing Homepage

On clicking, the control will be transferred to the next page that acts as the main service provider for this web site. On the Control Center page click on “Shortcut to Electronic Outsourcing DSS”(Figure A.2). When the above link is clicked a window will pop up . On this window click on “Save File” (Figure A.2). When the save file

button is clicked, the computer will ask the user where to store the file. The user will be required to specify the drive where he wants the file to be located. Once the file has been stored at the specified location, it can easily be used by unzipping it.

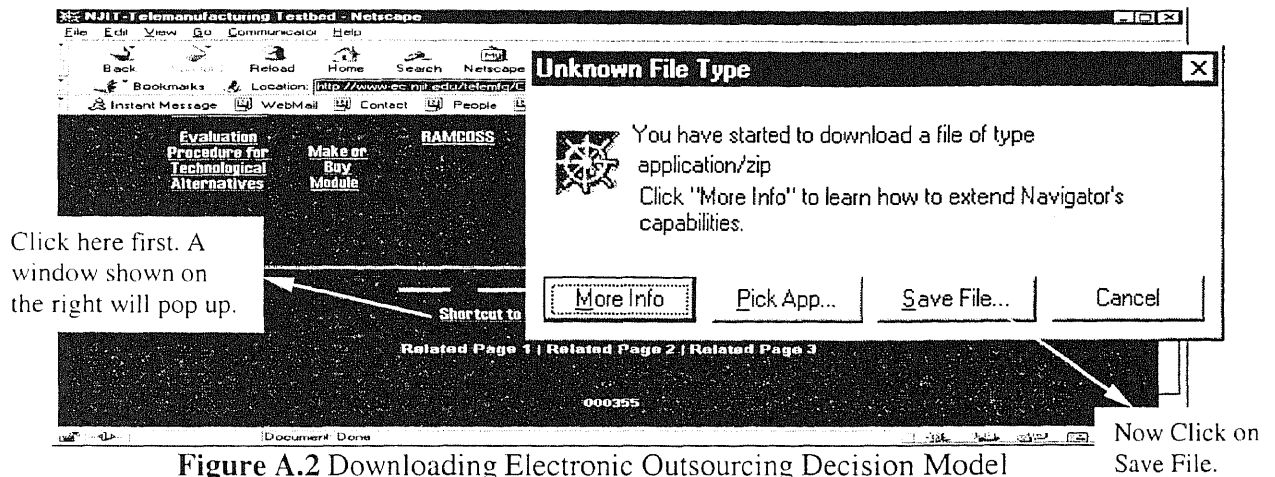


Figure A.2 Downloading Electronic Outsourcing Decision Model

II. *Using the Decision Software:* By clicking on Enter on the first screen, the user will be taken to the Menu Screen, which has three options, two for the available modules and

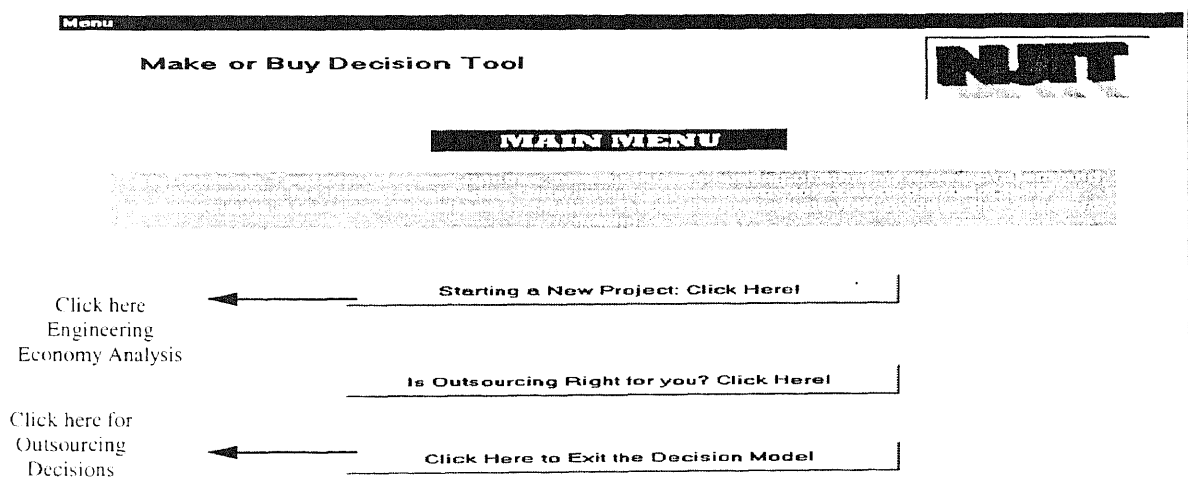


Figure A.3 Main Menu Screen for Electronic Outsourcing Model

the third for exiting the model. Option one is for evaluating alternative investment proposals and option two is for determining whether to continue producing in-house or to outsource production activity to an outside service provider.

Using Module A: Click on the option that says “Starting a New Project: Click here!”. The control is transferred to the Main screen of this module that will look like the one shown below in figure A.4.

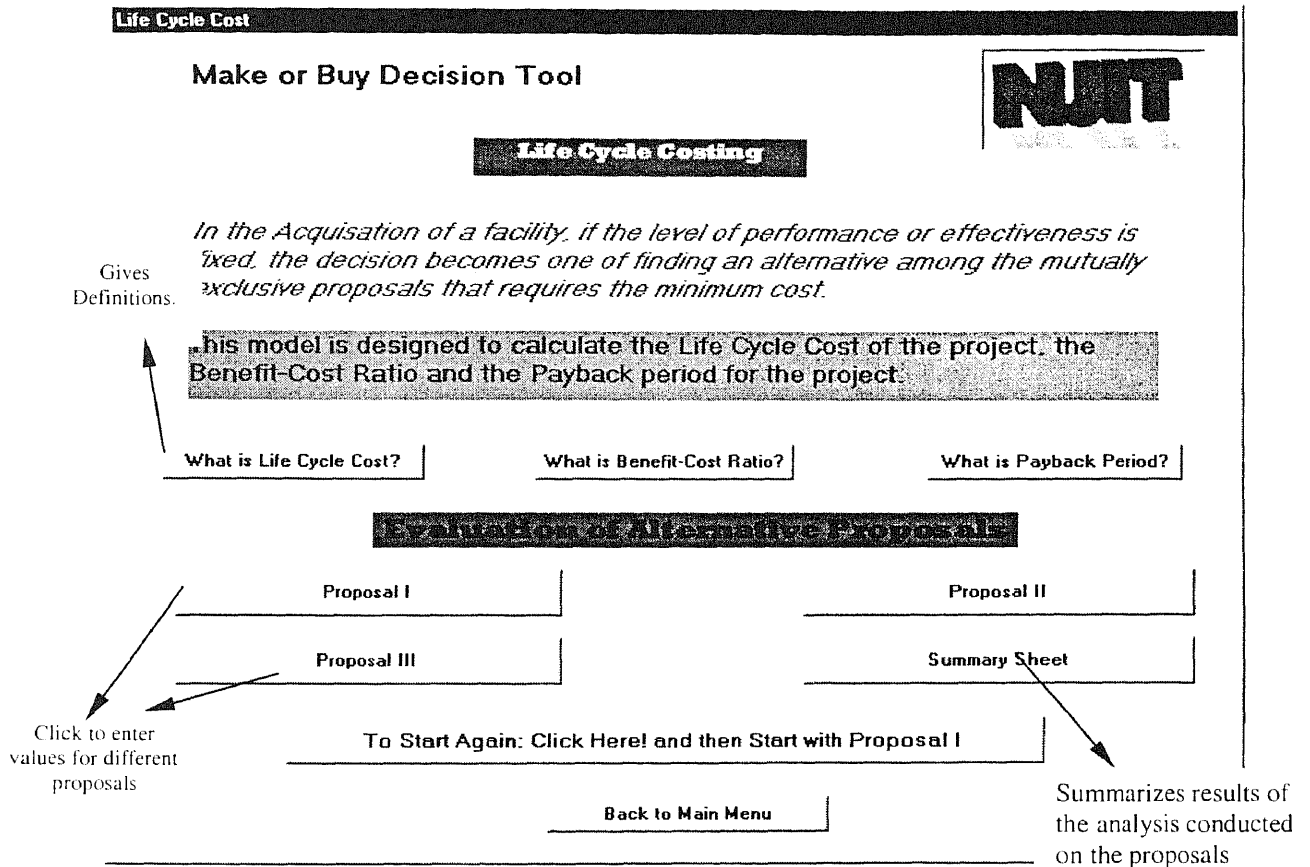


Figure A.4 Life Cycle Costing Module

Click on the proposal button to enter values pertaining to that proposal. This form also provides some basic definitions, like Benefit-Cost Ratio and Payback Period that may be useful in the analysis process. When Proposal I button is clicked a blank form as shown in figure A.5 appears where the user will be required to enter the values. Please note that only number values are allowed and no commas are necessary. The user should fill all the blanks or must enter a zero. After filling up all the blanks, click

Proposal I

Make or Buy Decision Tool

Proposal I

Proposal I

a). Enter the initial cost of the Project

b). Enter the annual operating and maintenance costs associated with the project

c). Enter the estimated annual benefits

d). Enter the Salvage value. (if none , then enter 0)

e). Enter Minimum Attractive Rate of Return.

f). Enter the estimated life of the Project.

Click after filling up the form

Continue

Reset

Back

Empties all the blanks.

NUIT

Figure A.5 Form for Entering Proposal values

on the Continue button provided on the form to go to the next step. The Reset button will empty all the blanks. The next form will provide the results of the analysis conducted by the model on proposal I (Figure A.6).

Evaluation I

Make or Buy Decision Tool

Proposal I- Evaluation

Present Value of Cash Outlays

Present value of Cash Inflows

Present value of Cash Inflows

Present value of Cash Inflows

Present value of Cash Inflows

[A Benefit-Cost Ratio $>$ or $=$ 1 is required for a project to be accepted.]

Click for Proposal II Form.

Continue to Alternative II

Back to Prev. Sheet

Back to Start Page

Click, To Change values for Proposal I

645811

370271

275540

0.573342665268941

NUIT

Figure A.6 Result form for Proposal

The user can go back and make changes to the Proposal values entered by clicking on "Back to Prev. Sheet" button. By clicking on the Continue button provided on the form the user can similarly complete other investment proposals. A complete

summary of the results on the analysis conducted on the proposals can be viewed on the Summary Sheet that can be accessed from the Main screen of this module or from the Result sheet of analysis III. The typical summary sheet looks like the one shown below in figure A.7. The sheet summarizes all the results for making comparisons

Summary Sheet

Make or Buy Decision Tool

NUT
NUT

The results of the analysis of the various alternative proposals have been summarized in the table shown below.

Proposal	Present Cost	Buy Inflow	Present Cost	Benefit-Cost Ratio	Payoff
I	645811	370271	275540	0.573342665268941	26
II	421764	2380381	-1958617	5.6438695573828	1
III	592067	270480	321587	0.456840188694861	32

Note: Select the proposal that costs the minimum (Present Cost) and has the highest Benefit-Cost Ratio.

Back to Start Page

Figure A.7 Summary Sheet

between alternatives easy and thereby helping in easy decision making. To start a new analysis the user can click on “Back to Start Page” button on this form. The main form of this module will come up again and on that form the user can start a new analysis by clicking on “To Start Again: Click here! And then Start with Proposal I” button. This will reset all the forms and the user can start a new analysis.

Using Module B: On the Main Menu Screen click on the option that says, “Is Outsourcing right for you, Click here”. The user will now be faced with a set of questions and based on the answers provided will perform the necessary analysis. The question forms will look like the one shown below in figure A.8.

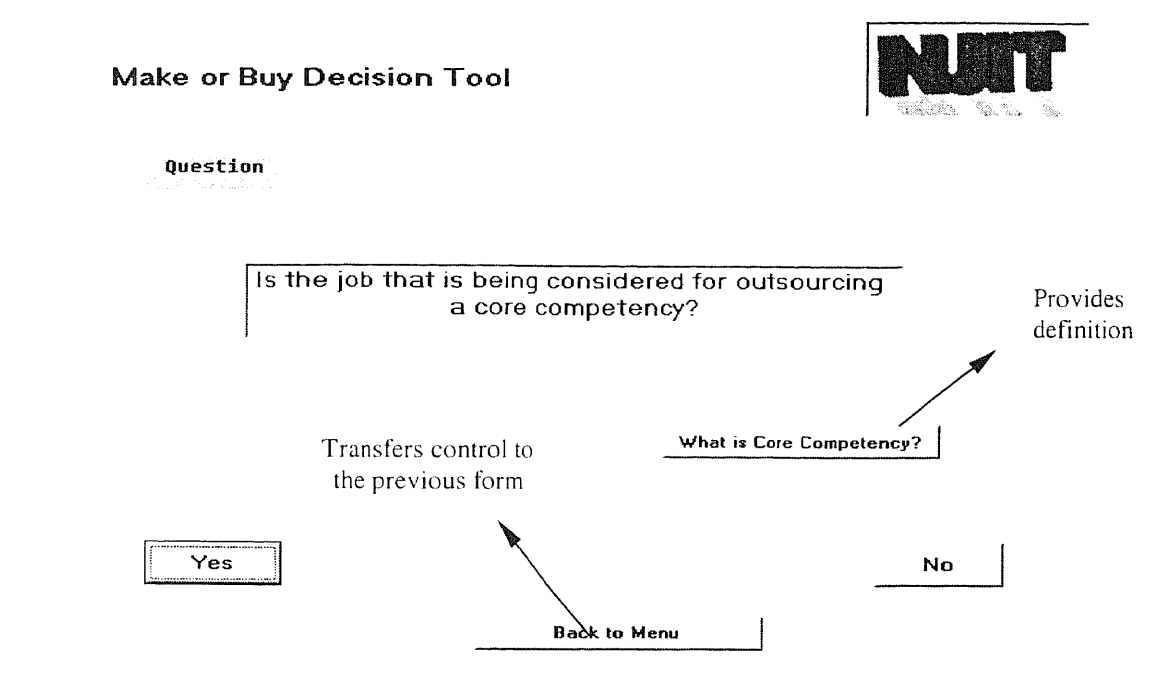


Figure A.8 A sample question form for Module B

The user here is required to answer in yes and no's based on his/her preference. At anytime, if the user feels that he / she has answered a question wrongly, the back button can transfer the control back to the previous question where the user can make the necessary changes. This module can perform Activity Based Costing, calculate annual cost of production, annual cost of purchase, and a break-even analysis. The Activity Based Costing form is shown in figure A.9. This form also can provide some basic definitions that may be useful in filling up the data on the form. The user must however be always careful to enter only number values in the blanks and never leave

a blank empty. The unit cost of production calculated from the ABC analysis will be used for calculating the annual cost of production. The forms for calculating cost of

Activity Based Costing

Make or Buy Decision Tool

NUT

Activity Based Costing

The decision tool uses Activity Based Costing to calculate the unit cost of production. Enter the following data and then continue to the next screen.

Units Produced Per Year	<input style="width: 90%;" type="text"/>	
Prime Costs	<input style="width: 90%;" type="text"/>	
Direct Labor Hours	<input style="width: 90%;" type="text"/>	
Machine Hours	<input style="width: 90%;" type="text"/>	
Number of Production Runs	<input style="width: 90%;" type="text"/>	
Number of Moves	<input style="width: 90%;" type="text"/>	

Probability of Success Indicator

Machine Setup Costs	<input style="width: 90%;" type="text"/>	Materials Handling Costs	<input style="width: 90%;" type="text"/>
Power Costs	<input style="width: 90%;" type="text"/>	Inspection Costs	<input style="width: 90%;" type="text"/>

<input style="width: 90%;" type="button" value="Continue"/>	<input style="width: 90%;" type="button" value="Back"/>	<input style="width: 90%;" type="button" value="Reset"/>	<input style="width: 90%;" type="button" value="To Exit Model"/>
---	---	--	--

Gives definitions

What are Prime Costs?

What are Direct labor hrs?

What are Production runs?

What is a "Move"?

Figure A.9 Activity Based Costing

production or purchase and the forms for break-even analysis follow the ABC analysis and can be used easily. A performance index to calculate the probability of

PSI

Make or Buy Decision Tool

NUT

Probability of Success Indicator

After comparing the costs associated with each approach, the next task is to calculate the Probability of Success Indicator (PSI). The PSI is a number lying in the range of 0-100, which is assigned to projects using the scoring scheme given below. The PSI gives a measure of how likely the project is to complete successfully. It uses a questionnaire of eight steps as they relate to a particular project and the PSI is calculated by applying a score to each of those eight steps. Score is directly proportional to the probability of success. The maximum possible scores are as follows:


Step	Score	Totals
1	20	
2	20	
3	10	
4	10	
5	10	total=70%
6	10	
7	10	
8	10	total=30%

<input style="width: 90%;" type="button" value="Continue"/>	<input style="width: 90%;" type="button" value="Back"/>
---	---

Figure A.10 Probability of Success Indicator Form

success of the project is available with this module. This can be used by following the instructions and scoring scheme provided on the form shown in figure 4.10. The proceeding form will list the factors considered for the analysis. The user will be required to assign scores to each factor based on the rating scale relevant to that factor, in this form, shown in figure A.11. Here also, care must be taken to score each

PSI



Make or Buy Decision Tool

Enter Scores if production is carried In-house

Step	Possible	Actual	Totals
Goal	20	<input type="text"/>	
Tasklist	20	<input type="text"/>	
Leadership	10	<input type="text"/>	
Assign People	10	<input type="text"/>	
Margin for Error	10	<input type="text"/>	<input type="text"/>
Management Style	10	<input type="text"/>	
Awareness	10	<input type="text"/>	
Communication	10	<input type="text"/>	<input type="text"/>
		Grand Total	<input type="text"/>

Continue

Reset

Back to Steps

Figure A.11 Scoring Sheet for PSI Analysis

factor and fill in all blanks. On the whole, the decision model is easy to use and can make decision making simpler and less tedious.

APPENDIX B

SOURCE CODE FOR ELECTRONIC OUTSOURCING DSS

In this appendix, the source codes for some of the main forms used in the decision software have been provided. The DSS uses Visual Basic and JavaScript.

I. Code for Menu Screen of Life Cycle Costing Module (A)

```
Private Sub Command1_Click()
```

```
MsgBox "Life Cycle Cost is the cost that refers to the present value of acquisition, operation, and maintenance of a facility over the planning horizon."
```

```
End Sub
```

```
Private Sub Command2_Click()
```

```
MsgBox "Benefit-Cost Ratio is defined as the ratio of the discounted benefits to the discounted costs of an investment with reference to the same point in time. The benefit-cost ratio is also sometimes referred to as the Profitability Index. For a project to be acceptable this ratio should be greater than or equal to 1."
```

```
End Sub
```

```
Private Sub Command3_Click()
```

```
MsgBox "Payback Period refers to length of time within which early receipts from an investment can repay disbursements incurred during the time span."
```

```
End Sub
```

```
Private Sub Command4_Click()
```

```
Proposal1.Show
```

```
Unload Me
```

```
End Sub
```

```
Private Sub Command5_Click()
```

```
Prop2.Show
```

```
Unload Me
```

```
End Sub
```

```
Private Sub Command6_Click()
```

```
prop3.Show
```

```
Unload Me
```

```
End Sub
```

```
Private Sub Command7_Click()
```

```
sum.Show
```

```
Unload Me
```

```
End Sub
```

```
Private Sub Command8_Click()
```

```
Proposal1.txt1 = ""
```

```
Proposal1.txt2 = ""
```

```

Proposal1.txt3 = ""
Proposal1.txt4 = ""
Proposal1.txt5 = ""
Proposal1.txt6 = ""
Prop2.txt1 = ""
Prop2.txt2 = ""
Prop2.txt3 = ""
Prop2.txt4 = ""
Prop2.txt5 = ""
Prop2.txt6 = ""
prop3.txt1 = ""
prop3.txt2 = ""
prop3.txt3 = ""
prop3.txt4 = ""
prop3.txt5 = ""
prop3.txt6 = ""
End Sub

```

```

Private Sub Command9_Click()
Menu.Show
Unload Me
End Sub

```

II. Code for Proposal Form (Module A)

```

Private Sub cmdreset_Click()
txt1 = ""
txt2 = ""
txt3 = ""
txt4 = ""
txt5 = ""
txt6 = ""
End Sub

```

```

Private Sub Command1_Click()
Form17.Show
Unload Me
End Sub

```

```

Private Sub Command2_Click()
Dim a As Long, b As Long, c As Long, d As Long, e As Long, f As Long
a = Proposal1.txt1
b = Proposal1.txt2
c = Proposal1.txt3
d = Proposal1.txt4
e = Proposal1.txt5

```

```

f = Proposal1.txt6
Eval1.txt1 = a + (b * ((1 + e / 100) ^ f - 1)) / (e / 100 * (1 + e / 100) ^ f)
Eval1.txt1 = Fix(Eval1.txt1)
Eval1.txt2 = d * (1 + e / 100) ^ (-f) + (c * ((1 + e / 100) ^ f - 1)) / (e / 100 * (1 + e / 100) ^ f)
Eval1.txt2 = Fix(Eval1.txt2)
Eval1.txt3 = Fix(Eval1.txt1 - Eval1.txt2)
Eval1.txt4 = Eval1.txt2 / Eval1.txt1
Eval1.txt5 = (a) / (c - b)
Eval1.txt5 = Fix(Eval1.txt5)
sum.txt1 = Eval1.txt1
sum.txt2 = Eval1.txt2
sum.txt3 = Eval1.txt3
sum.txt4 = Eval1.txt4
sum.txt5 = Eval1.txt5
Eval1.Show
Proposal1.Hide
End Sub

Private Sub txt1_LostFocus()
If Proposal1.txt1 = "" Then MsgBox "Enter a value!"
End Sub

Private Sub txt2_LostFocus()
If Proposal1.txt2 = "" Then MsgBox "Enter a value!"
End Sub

Private Sub txt3_LostFocus()
If Proposal1.txt3 = "" Then MsgBox "Enter a value!"
End Sub

Private Sub txt4_LostFocus()
If Proposal1.txt4 = "" Then MsgBox "Enter a value!"
End Sub

Private Sub txt5_LostFocus()
If Proposal1.txt5 = "" Then MsgBox "Enter a value!"
End Sub

Private Sub txt6_LostFocus()
If Proposal1.txt6 = "" Then MsgBox "Enter a value!"
End Sub

```

III. Code for Life Cycle Costing Module(A) Written using JavaScript

```

<html>

<head>
<title>New Page 2</title>
<meta name="GENERATOR" content="Microsoft FrontPage 3.0">
<script LANGUAGE="JavaScript">

<!-- Begin
function calculate1(form) {
var a=eval(form.cost1.value)
var b=eval(form.oper1.value)
var c=eval(form.benefits1.value)
var d=eval(form.salvage1.value)
var e=eval(form.rate1.value)
var f=eval(form.life1.value)

var pow1 = Math.pow((1 + (e / 100)),f)
var pow2 = Math.pow((1 + (e / 100)),(-f))
var p=a + ((b * (pow1 - 1)) / ((e / 100) * pow1))
var q=(d * pow2) + ((c * (pow1 - 1)) / ((e / 100) * pow1))
var r=p-q
var s=q/p
var t=a/(c-b)
form.cashout1.value = p
form.cashin1.value = q
form.precost1.value = r
form.bencost1.value = s
form.payback1.value = t
}

function calculate2(form) {
var a=eval(form.cost2.value)
var b=eval(form.oper2.value)
var c=eval(form.benefits2.value)
var d=eval(form.salvage2.value)
var e=eval(form.rate2.value)
var f=eval(form.life2.value)

var pow1 = Math.pow((1 + (e / 100)),f)
var pow2 = Math.pow((1 + (e / 100)),(-f))
var p=a + ((b * (pow1 - 1)) / ((e / 100) * pow1))
var q=(d * pow2) + ((c * (pow1 - 1)) / ((e / 100) * pow1))
var r=p-q
var s=q/p
var t=a/(c-b)
form.cashout2.value = p
form.cashin2.value = q
form.precost2.value = r
form.bencost2.value = s
form.payback2.value = t
}

//line 55
function calculate3(form) {
var a=eval(form.cost3.value)
var b=eval(form.oper3.value)
var c=eval(form.benefits3.value)
var d=eval(form.salvage3.value)
var e=eval(form.rate3.value)
var f=eval(form.life3.value)

```

```

var pow1 = Math.pow((1 + (e / 100)), f)
var pow2 = Math.pow((1 + (e / 100)), (-f))
var p=a + ((b * (pow1 - 1)) / ((e / 100) * pow1))
var q=(d * pow2) + ((c * (pow1 - 1)) / ((e / 100) * pow1))
var r=p-q
var s=q/p
var t=a/(c-b)
form.cashout3.value = p
form.cashin3.value = q
form.precost3.value = r
form.bencost3.value = s
form.payback3.value = t
}

function calculate(form){
//first set of values
var a1=eval(form.cost1.value)
var b1=eval(form.oper1.value)
var c1=eval(form.benefits1.value)
var d1=eval(form.salvage1.value)
var e1=eval(form.rate1.value)
var f1=eval(form.lifel.value)

var pow11 = Math.pow((1 + (e1 / 100)), f1)
var pow21 = Math.pow((1 + (e1 / 100)), (-f1))
var p1=a1 + ((b1 * (pow11 - 1)) / ((e1 / 100) * pow11))
var q1=(d1 * pow21) + ((c1 * (pow11 - 1)) / ((e1/ 100) * pow11))
var r1=p1-q1
var s1=q1/p1
var t1=a1/(c1-b1)
form.cashout1.value = p1
form.cashin1.value = q1
form.precost1.value = r1
form.bencost1.value = s1
form.payback1.value = t1

//Second set of Values
var a2=eval(form.cost2.value)
var b2=eval(form.oper2.value)
var c2=eval(form.benefits2.value)
var d2=eval(form.salvage2.value)
var e2=eval(form.rate2.value)
var f2=eval(form.life2.value)

var pow12 = Math.pow((1 + (e2 / 100)), f2)
var pow22 = Math.pow((1 + (e2 / 100)), (-f2))
var p2=a2 + ((b2 * (pow12 - 1)) / ((e2 / 100) * pow12))
var q2=(d2 * pow22) + ((c2 * (pow12 - 1)) / ((e2 / 100) * pow12))
var r2=p2-q2
var s2=q2/p2
var t2=a2/(c2-b2)
form.cashout2.value = p2
form.cashin2.value = q2
form.precost2.value = r2
form.bencost2.value = s2
form.payback2.value = t2

//line 122
//third set of values
var a3=eval(form.cost3.value)
var b3=eval(form.oper3.value)
var c3=eval(form.benefits3.value)
var d3=eval(form.salvage3.value)

```



```

var e3=eval(form.rate3.value)
var f3=eval(form.life3.value)

var pow13 = Math.pow((1 + (e3 / 100)),f3)
var pow23 = Math.pow((1 + (e3 / 100)),(-f3))
var p3=a3 + ((b3 * (pow13 - 1)) / ((e3 / 100) * pow13))
var q3=(d3 * pow23) + ((c3 * (pow13 - 1)) / ((e3 / 100) * pow13))
var r3=p3-q3
var s3=q3/p3
var t3=a3/(c3-b3)
form.cashout3.value = p3
form.cashin3.value = q3
form.precost3.value = r3
form.bencost3.value = s3
form.payback3.value = t3
}

//To get the text when mouse passes over it
function gettext(txt){
    FORM1.textbox.value = txt
    return true
}

function goBack(){
    parent.location='Lifecycle.htm'
}

function goFront(){
    parent.location='Control%20Center.html'
}

function validate1 (){
    if (document.FORM1.cost1.value == "")
    {
        alert("Please enter initial cost of Project.")
        document.FORM1.cost1.focus()
        return false
    }
    else if (document.FORM1.oper1.value == "")
    {
        alert("Enter Annual Operation and Maintenance Costs.")
        document.FORM1.oper1.focus()
        return false
    }
    else if (document.FORM1.benefits1.value == "")
    {
        alert("Please enter annual expected benefits.")
        document.FORM1.benefits1.focus()
        return false
    }
    else if (document.FORM1.salvagel.value == "")
    {
        alert("Please enter expected salvage value.")
        document.FORM1.salvagel.focus()
        return false
    }
    else if (document.FORM1.rate1.value == "")
    {
        alert("Please enter minimum rate of return.")
        document.FORM1.rate1.focus()
        return false
    }
    else if (document.FORM1.lifel.value == "")
    {
        alert("Please enter expected life of project.")
        document.FORM1.lifel.focus()
        return false
    }
}

```

```

    }
    else calculate1(FORM1)
}

function validate2 (){
    if (document.FORM1.cost2.value == "")
    { alert("Please enter initial cost of Project.")
      document.FORM1.cost2.focus()
      return false
    }
    else if (document.FORM1.oper2.value == "")
    { alert("Enter Annual Operation and Maintenance Costs.")
      document.FORM1.oper2.focus()
      return false
    }
    else if (document.FORM1.benefits2.value == "")
    { alert("Please enter annual expected benefits.")
      document.FORM1.benefits2.focus()
      return false
    }
    else if (document.FORM1.salvage2.value == "")
    { alert("Please enter expected salvage value.")
      document.FORM1.salvage2.focus()
      return false
    }
    else if (document.FORM1.rate2.value == "")
    {
      alert("Please enter minimum rate of return.")
      document.FORM1.rate2.focus()
      return false
    }
    else if (document.FORM1.life2.value == "")
    {
      alert("Please enter expected life of project.")
      document.FORM1.life2.focus()
      return false
    }
    else calculate2(FORM1)
}

function validate3 (){
    if (document.FORM1.cost3.value == "")
    { alert("Please enter initial cost of Project.")
      document.FORM1.cost3.focus()
      return false
    }
    else if (document.FORM1.oper3.value == "")
    { alert("Enter Annual Operation and Maintenance Costs.")
      document.FORM1.oper3.focus()
      return false
    }
    else if (document.FORM1.benefits3.value == "")
    { alert("Please enter annual expected benefits.")
      document.FORM1.benefits3.focus()
      return false
    }
    else if (document.FORM1.salvage3.value == "")
    { alert("Please enter expected salvage value.")
      document.FORM1.salvage3.focus()
      return false
    }
    else if (document.FORM1.rate3.value == "")
    {

```



```

        name="cost2" size="10" tabindex="8"></td>
        <td height="23" width="248" align="center" bgcolor="#FF80C0"><div
align="center"><center><p><input
        type="text" name="cost3" size="10" tabindex="15"></td>
</tr>
<tr align="center">
        <td height="23" width="446" align="left" bgcolor="#FF80C0"><div
align="center"><center><p><a
        onMouseover="gettext(&quot;Estimated annual expenditure on operating and
maintaining the project infrastructure&quot;)"><font
        color="#000000"><strong><small>ANNUAL OPERATION AND MAINTENANCE
COST</small></strong></font></a></td>
        <td height="23" width="101" align="center" bgcolor="#FF80C0"><input
type="text"
        name="oper1" size="10" tabindex="2"></td>
        <td height="23" width="167" align="center" bgcolor="#FF80C0"><input
type="text"
        name="oper2" size="10" tabindex="9"></td>
        <td height="23" width="248" align="center" bgcolor="#FF80C0"><div
align="center"><center><p><input
        type="text" name="oper3" size="10" tabindex="16"></td>
</tr>
<tr align="center">
        <td height="23" width="446" align="left" bgcolor="#FF80C0"><div
align="center"><center><p><a
        onMouseover="gettext(&quot;Estimated annual benefits to be generated by
the Project&quot;)"><font
        color="#000000"><strong><small>ESTIMATED ANNUAL
BENEFITS</small></strong></font></a></td>
        <td height="23" width="101" align="center" bgcolor="#FF80C0"><input
type="text"
        name="benefits1" size="10" tabindex="3"></td>
        <td height="23" width="167" align="center" bgcolor="#FF80C0"><input
type="text"
        name="benefits2" size="10" tabindex="10"></td>
        <td height="23" width="248" align="center" bgcolor="#FF80C0"><div
align="center"><center><p><input
        type="text" name="benefits3" size="10" tabindex="17"></td>
</tr>
<tr align="center">
        <td height="23" width="446" align="left" bgcolor="#FF80C0"><div
align="center"><center><p></a><a
        onMouseover="gettext(&quot;Salvage value expected at the termination of
the Project&quot;)"><font
        color="#000000"><strong><small>SALVAGE VALUE (O IF
NONE)</small></strong></font></a></td>
        <td height="23" width="101" align="center" bgcolor="#FF80C0"><input
type="text"
        name="salvage1" size="10" tabindex="4"></td>
        <td height="23" width="167" align="center" bgcolor="#FF80C0"><input
type="text"
        name="salvage2" size="10" tabindex="11"></td>
        <td height="23" width="248" align="center" bgcolor="#FF80C0"><div
align="center"><center><p><input
        type="text" name="salvage3" size="10" tabindex="18"></td>
</tr>
<tr align="center">
        <td height="23" width="446" align="left" bgcolor="#FF80C0"><div
align="center"><center><p></a><a
        onMouseover="gettext(&quot;Minimum Attractive Rate of Return acceptable
by the company/ user for the Project&quot;)"><font
        color="#000000"><strong><small>MINIMUM RATE OF
RETURN</small></strong></font></a></td>

```



```

onmouseover="gettext(&quot;Number of Years the Project is expected to
last&quot;);"><font
color="#000080"><strong><small>PRESENT VALUE OF CASH
INFLOWS</strong></small></font></a></td>
<td height="22" width="148" align="center" bgcolor="#80FF80"><div
align="center"><center><p><a
onmouseover="gettext(&quot;Number of Years the Project is expected to
last&quot;);"><font
color="#000080"><strong><small>PRESENT COST OF
PROJECT</small></strong></font></a></td>
<td height="22" width="166" align="center" bgcolor="#80FF80"><div
align="center"><center><p><a
onmouseover="gettext(&quot;Number of Years the Project is expected to
last&quot;);"><font
color="#000080"><strong><small>BENEFIT-COST RATIO
</small></strong></font></a></td>
<td height="22" width="145" align="center" bgcolor="#80FF80"><div
align="center"><center><p><strong><small><a
onmouseover="gettext(&quot;Number of Years the Project is expected to
last&quot;);"><font
color="#000080">PAYBACK PERIOD</font></a></small></strong></td>
<a onmouseover="gettext(&quot;Number of Years the Project is expected to
last&quot;);">
</tr>
<tr align="center">
</a><td height="22" width="260" bgcolor="#80FF80"><div
align="center"><center><p><font
color="#000000"><strong><a
onmouseover="gettext(&quot;Number of Years the Project is expected to
last&quot;);">Proposal
I:</a></strong></font></td>
<a onmouseover="gettext(&quot;Number of Years the Project is expected to
last&quot;);"><td
height="22" width="261" align="center" bgcolor="#80FF80"><input
type="text"
name="cashout1" size="10" onfocus="this.blur()"></td>
<td height="22" width="204" align="center" bgcolor="#80FF80"><input
type="text"
name="cashin1" size="10" onfocus="this.blur()"></td>
<td height="22" width="148" align="center" bgcolor="#80FF80"><input
type="text"
name="precost1" size="10" onfocus="this.blur()"></td>
<td height="22" width="166" align="center" bgcolor="#80FF80"><input
type="text"
name="bencost1" size="10" onfocus="this.blur()"></td>
<td height="22" width="145" align="center" bgcolor="#80FF80"><input
type="text"
name="payback1" size="10" onfocus="this.blur()"></td>
</tr>
<tr align="center">
</a><td height="23" width="260" bgcolor="#80FF80"><div
align="center"><center><p><font
color="#000000"><strong><a
onmouseover="gettext(&quot;Number of Years the Project is expected to
last&quot;);">Proposal
II:</a></strong></font></td>
<a onmouseover="gettext(&quot;Number of Years the Project is expected to
last&quot;);"><td
height="23" width="261" align="center" bgcolor="#80FF80"><input
type="text"
name="cashout2" size="10" onfocus="this.blur()"></td>
<td height="23" width="204" align="center" bgcolor="#80FF80"><input
type="text"

```


End Sub

```
Private Sub Command2_Click()  
Form3.Show  
Unload Me  
End Sub
```

```
Private Sub Command3_Click()  
MsgBox "Core competencies are the essential and enduring tenets of an organization. A  
small set of timeless guiding principles, core values require no external justification; they  
have intrinsic value and importance to those inside the organization. The point is that a  
company should decide what values it holds to be the core, largely independent of the  
current environment, competitive requirements, or management fads. Only a few values  
can be truly core--that is, so fundamental and deeply held that they will change seldom, if  
ever. These core values guide the business decisions we make and our day to day  
operations."  
End Sub
```

```
Private Sub Command4_Click()  
Menu.Show  
Unload Me  
End Sub
```

```
Private Sub Command1_Click()  
Form6.Show  
Unload Me  
End Sub
```

```
Private Sub Command2_Click()  
Form13b.Show  
Unload Me  
End Sub
```

```
Private Sub Command3_Click()  
Form1.Show  
Unload Me  
End Sub
```

```
Private Sub Command1_Click()  
Form3b.Show  
Unload Me  
End Sub
```

```
Private Sub Command2_Click()
```



```
Form21.Show
Unload Me
End Sub
```

```
Private Sub Command3_Click()
Form2.Show
End Sub
```

V. *Activity Based Costing Code*

```
Private Sub Command1_Click()
Dim a, b As Long
Dim c, d As Long
a = Form18.txt7
b = Form18.txt8
Form19.txt1 = a
Form19.txt2 = b
Form19.txt3 = a + b
c = Form18.txt9
d = Form18.txt10
Form19.txt4 = c
Form19.txt5 = d
Form19.txt6 = c + d
Form19.txt7 = Form19.txt3 / Form18.txt5
Form19.txt8 = Form19.txt6 / Form18.txt4
Form20.txt1 = Form18.txt2
Form20.txt5 = Form18.txt1
Form19.Show
Form18.Hide
End Sub
```

```
Private Sub Command2_Click()
Form9.Show
Form18.Hide
End Sub
```

```
Private Sub Command3_Click()
Form18.txt1 = ""
Form18.txt2 = ""
Form18.txt3 = ""
Form18.txt4 = ""
Form18.txt5 = ""
Form18.txt6 = ""
Form18.txt7 = ""
Form18.txt8 = ""
Form18.txt9 = ""
Form18.txt10 = ""
```

End Sub

Private Sub Command4_Click()

MsgBox "Prime cost is the sum of direct materials cost and direct labor cost and is traced directly to the part/product being manufactured."

End Sub

Private Sub Command5_Click()

MsgBox "A Move is the material handling activity associated with the production process."

End Sub

Private Sub Command6_Click()

MsgBox "Production runs represents the number of times production is carried out. "

End Sub

Private Sub Command7_Click()

End

End Sub

Private Sub Command8_Click()

MsgBox "Direct labor hours are the hours that are traceable to the good or services being produced and are used for converting raw materials into the final product."

End Sub

Private Sub txt1_LostFocus()

If Form18.txt1 = "" Then MsgBox "Enter a Value"

End Sub

Private Sub txt10_LostFocus()

If Form18.txt10 = "" Then MsgBox "Enter a Value"

End Sub

Private Sub txt2_LostFocus()

If Form18.txt2 = "" Then MsgBox "Enter a Value"

End Sub

Private Sub txt3_LostFocus()

If Form18.txt3 = "" Then MsgBox "Enter a Value"

End Sub

Private Sub txt4_LostFocus()

If Form18.txt4 = "" Then MsgBox "Enter a Value"

End Sub

Private Sub txt5_LostFocus()

```
If Form18.txt5 = "" Then MsgBox "Enter a Value"
End Sub
```

```
Private Sub txt6_LostFocus()
If Form18.txt6 = "" Then MsgBox "Enter a Value"
End Sub
```

```
Private Sub txt7_LostFocus()
If Form18.txt7 = "" Then MsgBox "Enter a Value"
End Sub
```

```
Private Sub txt8_LostFocus()
If Form18.txt8 = "" Then MsgBox "Enter a Value"
End Sub
```

```
Private Sub txt9_LostFocus()
If Form18.txt9 = "" Then MsgBox "Enter a Value"
End Sub
```

VI. *Cost Analysis for calculating Cost of Production*

```
Private Sub cmdreset_Click()
txt1 = ""
txt2 = ""
txt3 = ""
txt4 = ""
txt5 = ""
End Sub
```

```
Private Sub Command1_Click()
Options.Show
Unload Me
End Sub
```

```
Private Sub Command2_Click()
Dim a, b, c, d, e As Long
a = DailyCost.txt1
b = DailyCost.txt2
c = DailyCost.txt3
d = DailyCost.txt4
e = DailyCost.txt5
Makecost.txtans = (a * b) + ((1 - b / c) ^ 0.5) * (2 * a * b * e * d) ^ 0.5
Makecost.txtans = Fix(Makecost.txtans)
Makecost.Show
DailyCost.Hide
End Sub
```

```
Private Sub Command3_Click()  
MsgBox "Unit cost of production can be calculated using the Activity Based Costing  
System or anyother method that the user may find appropriate. This model also provides  
an ABC system to determine this value."  
End Sub
```

```
Private Sub Command4_Click()  
MsgBox "Demand rate for a product will be based on customers demand and forecasts."  
End Sub
```

```
Private Sub Command5_Click()  
MsgBox "This is the cost of carrying one unit of stock for one year."  
End Sub
```

```
Private Sub Command6_Click()  
MsgBox "This is the cost associated with placing and receiving an order. This could  
include costs for processing an order, insurance for shipment, or unloading costs."  
End Sub
```

```
Private Sub Command7_Click()  
MsgBox "This is determined using the available machine capacity, the cycle times of the  
machine, the labor hours involved and other factors."  
End Sub
```

```
Private Sub txt1_LostFocus()  
If DailyCost.txt1 = "" Then MsgBox ("Enter a value!")  
End Sub
```

```
Private Sub txt2_LostFocus()  
If DailyCost.txt2 = "" Then MsgBox ("Enter a value!")  
End Sub
```

```
Private Sub txt3_LostFocus()  
If DailyCost.txt3 = "" Then MsgBox ("Enter a value!")  
End Sub
```

```
Private Sub txt4_LostFocus()  
If DailyCost.txt4 = "" Then MsgBox ("Enter a value!")  
End Sub
```

```
Private Sub txt5_LostFocus()  
If DailyCost.txt5 = "" Then MsgBox ("Enter a value!")  
End Sub
```

VII. Code for Break Even Analysis

```
Private Sub cmdreset_Click()  
txt1 = ""  
txt2 = ""  
txt3 = ""  
End Sub
```

```
Private Sub Command1_Click()  
Dim a, b, c As Long  
a = BreakEven.txt1  
b = BreakEven.txt2  
c = BreakEven.txt3  
MakeUnits.txtunits = a / (b - c)  
MakeUnits.txtunits = Fix(MakeUnits.txtunits)  
MakeUnits.Show  
BreakEven.Hide  
End Sub
```

```
Private Sub Command2_Click()  
Options.Show  
Unload Me  
End Sub
```

```
Private Sub Command3_Click()  
MsgBox "Fixed cost of production is the cost that is independent of the level of the  
production activity."  
End Sub
```

```
Private Sub Command4_Click()  
MsgBox "Variable cost of production is the cost that varies directly in proportion to the  
changes in the level of the production activity. This cost could include the cost of raw  
materials or the cost of cost of power."  
End Sub
```

```
Private Sub txt1_LostFocus()  
If BreakEven.txt1 = "" Then MsgBox ("Enter a value")  
End Sub
```

```
Private Sub txt2_LostFocus()  
If BreakEven.txt2 = "" Then MsgBox ("Enter a value")  
End Sub
```

```
Private Sub txt3_LostFocus()  
If BreakEven.txt3 = "" Then MsgBox ("Enter a value")  
End Sub
```

VIII. Code for Probability of Success Indicator Analysis

```
Private Sub cmdreset_Click()
```

```
txt1 = ""
```

```
txt2 = ""
```

```
txt3 = ""
```

```
txt4 = ""
```

```
txt5 = ""
```

```
txt6 = ""
```

```
txt7 = ""
```

```
txt8 = ""
```

```
txt9 = ""
```

```
txt10 = ""
```

```
txt11 = ""
```

```
End Sub
```

```
Private Sub Command1_Click()
```

```
Analysis.txt1 = PSI2.txt1
```

```
Analysis.txt2 = PSI2.txt2
```

```
Analysis.txt3 = PSI2.txt3
```

```
Analysis.txt4 = PSI2.txt4
```

```
Analysis.txt5 = PSI2.txt5
```

```
Analysis.txt6 = PSI2.txt6
```

```
Analysis.txt7 = PSI2.txt7
```

```
Analysis.txt8 = PSI2.txt8
```

```
Analysis.txt9 = PSI2.txt11
```

```
PSI3.Show
```

```
Unload Me
```

```
End Sub
```

```
Private Sub Command2_Click()
```

```
Dim a As Double, b As Double, c As Double, d As Double, e As Double, f As Double, g  
As Double, h As Double
```

```
a = PSI2.txt1
```

```
b = PSI2.txt2
```

```
c = PSI2.txt3
```

```
d = PSI2.txt4
```

```
e = PSI2.txt5
```

```
f = PSI2.txt6
```

```
g = PSI2.txt7
```

```
h = PSI2.txt8
```

```
PSI2.txt11 = a + b + c + d + e + f + g + h
```

```
PSI2.txt9 = a + b + c + d + e
```

```
PSI2.txt10 = f + g + h
```

```
End Sub
```

```
Private Sub Command3_Click()  
PSI1.Show  
Unload Me  
End Sub
```

```
Private Sub txt1_LostFocus()  
If PSI2.txt1 = "" Then MsgBox ("Enter a score") Else If PSI2.txt1 > 20 Then MsgBox ("  
Score should be less than 20")  
End Sub
```

```
Private Sub txt2_LostFocus()  
If PSI2.txt2 = "" Then MsgBox ("Enter a score") Else If PSI2.txt2 > 20 Then MsgBox ("  
Score should be less than 20")  
End Sub
```

```
Private Sub txt3_LostFocus()  
If PSI2.txt3 = "" Then MsgBox ("Enter a score") Else If PSI2.txt3 > 10 Then MsgBox ("  
Score should be less than 20")  
End Sub
```

```
Private Sub txt4_LostFocus()  
If PSI2.txt4 = "" Then MsgBox ("Enter a score") Else If PSI2.txt4 > 10 Then MsgBox ("  
Score should be less than 20")  
End Sub
```

```
Private Sub txt5_LostFocus()  
If PSI2.txt5 = "" Then MsgBox ("Enter a score") Else If PSI2.txt5 > 10 Then MsgBox ("  
Score should be less than 20")  
End Sub
```

```
Private Sub txt6_LostFocus()  
If PSI2.txt6 = "" Then MsgBox ("Enter a score") Else If PSI2.txt6 > 10 Then MsgBox ("  
Score should be less than 20")  
End Sub
```

```
Private Sub txt7_LostFocus()  
If PSI2.txt7 = "" Then MsgBox ("Enter a score") Else If PSI2.txt7 > 20 Then MsgBox ("  
Score should be less than 20")  
End Sub
```

```
Private Sub txt8_LostFocus()  
If PSI2.txt8 = "" Then MsgBox ("Enter a score") Else If PSI2.txt8 > 10 Then MsgBox ("  
Score should be less than 20")  
End Sub
```

APPENDIX C

HARDWARE REQUIREMENTS FOR CAD SOFTWARE

Hardware Notes -

Mechanical Design Last Updated: November 29, 1999

Management **DELL**

Intel Processor - Windows NT

Enterprise Partners

Pro/ENGINEER 2000i				
Pro/INTRALINK Data Server Release 1.2, Release 2.0				
Pro/INTRALINK Client Release 1.2, Release 2.0				
Pro/PDM Client Release 3.5				
Machine	Operating Systems	Graphics Hardware	Window Manager	Graphics Software
Precision WorkStation 410, 610	Windows NT 4.0	Intense3D Wildcat 4000	Windows NT 4.0	OpenGL
	Windows NT Japanese 4.0	Intergraph Intense3D Pro 3410T, 3410GT 3Diabs Oxygen GMX Evans & Sutherland AccelGalaxy Diamond Viper 770, FireGL 1, Permedia 2 8MB AGP		Win32 GDI
Precision WorkStation 210	Windows NT 4.0	Diamond Permedia 2 8MB AGP	Windows NT 4.0	OpenGL
	Windows NT Japanese 4.0			Win32 GDI
WorkStation 400	Windows NT 4.0	ELSA GLoria-XL	Windows NT 4.0	OpenGL
	Windows NT Japanese 4.0	ELSA GLoria-L/MX		Win32 GDI
WorkStation 400	Windows NT 4.0	Matrox Millennium	Windows NT 4.0	Win32 GDI
	Windows NT Japanese 4.0			

Pro/MECHANICA 2000				
Machine	Operating Systems	Graphics Hardware	Window Manager	Graphics Software
Precision WorkStation 410, 610	Windows NT 4.0	Intense3D Wildcat 4000	Windows NT 4.0	Win32 GDI
	Windows NT Japanese 4.0	Intergraph Intense3D Pro 3410T, 3410GT 3Diabs Oxygen GMX Evans & Sutherland AccelGalaxy Diamond Viper 770, FireGL 1, Permedia 2 8MB AGP		

Precision WorkStation 210	Windows NT 4.0 Windows NT Japanese 4.0	Diamond Permedia 2.8MB AGP	Windows NT 4.0	Win32 GDI
WorkStation 400	Windows NT 4.0 Windows NT Japanese 4.0	ELSA GLoria-XL	Windows NT 4.0	OpenGL Win32 GDI
WorkStation 400	Windows NT 4.0 Windows NT Japanese 4.0	ELSA GLoria-L/MX Matrox Millennium	Windows NT 4.0	Win32 GDI

Based on general platform support for Pro/MECHANICA (Intel-based PC), PTC expects these configurations to run, although each may

CDRS 2000i				
Machine	Operating Systems	Graphics Hardware	Window Manager	Graphics Software
Precision WorkStation 410, 610	Windows NT 4.0	Diamond Viper 770, FireGL 1 Intense3D Wildcat 4000 Intergraph Intense3D Pro 3410T, 3410GT 3DLabs Oxygen GMX Evans & Sutherland AccelGalaxy	Windows NT 4.0	OpenGL
WorkStation 400	Windows NT 4.0	ELSA GLoria-XL	Windows NT 4.0	OpenGL

Pro/FLY-THROUGH Release 21.0, Pro/Model.View Release 2.0				
Machine	Operating Systems	Graphics Hardware	Window Manager	Graphics Software
Precision WorkStation 410, 610	Windows NT 4.0 Windows NT Japanese 4.0	Intense3D Wildcat 4000 Intergraph Intense3D Pro 3410T, 3410GT 3DLabs Oxygen GMX Evans & Sutherland AccelGalaxy Diamond Viper 770, FireGL 1, Permedia 2.8MB AGP	Windows NT 4.0	OpenGL & Open Inventor 2.2
Precision WorkStation 210	Windows NT 4.0 Windows NT Japanese 4.0	Diamond Permedia 2.8MB AGP	Windows NT 4.0	OpenGL & Open Inventor 2.2
WorkStation 400	Windows NT 4.0	ELSA GLoria-XL ELSA GLoria-L/MX	Windows NT 4.0	OpenGL & Open Inventor 2.2

OpenGL is required and can be obtained from Microsoft. Open Inventor is required and is provided by PTC on the Pro/FLY-THROUGH CD.

Minimum Main Memory	64 MB for Pro/ENGINEER &
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Required	Pro/PDM Pro FLY-THROUGH 128 MB for Pro ENGINEER & Pro INTRALINK 96 MB for Pro MECHANICA 128 MB for CDRS 32 MB for Pro Model View
Minimum Available Disk Space	400 MB for Pro ENGINEER, Pro INTRALINK, Pro PDM, Pro FLY-THROUGH 870 MB for Pro MECHANICA 600 MB for CDRS 50 MB for Pro Model View
Swap Space	128 MB for Pro ENGINEER, Pro INTRALINK, Pro PDM, Pro FLY-THROUGH 200 MB for Pro MECHANICA 320 MB for CDRS 100 MB for Pro Model View
Network Requirements	Microsoft TCP/IP, Ethernet Network Adapter
File System	HPFS, NTFS
Monitor	1024 X 768 Minimum Resolution, 256 colors
Mouse	Microsoft NT approved 3-button mouse
Language Support	Pro/ENGINEER - English, French, German, Italian, Japanese, Korean, Spanish Pro INTRALINK - English, French, German, Italian, Japanese Pro/PDM - English, German, French, Japanese Pro/MECHANICA - English, German, Japanese CDRS - English Pro/FLY-THROUGH - English, German, French, Italian, Japanese Pro Model View - English, German, French, Italian, Japanese
Distribution Media	CD-ROM

NOTES:

1. The Pro/Web Link module requires Netscape Navigator 4.03.
2. The PHOTORENDERER module requires 16-bit (or higher) graphics on Intel-based Windows NT workstations.
3. Pro/PDM is supported running on a Windows NT workstation as a CLIENT only.
4. PTC products are tested and certified with standard Windows NT and Windows 9x LAN Manager network configurations. PTC products may utilize NFS from MS Windows, however PTC can only provide support for issues that occur on a certified configuration. All issues with windows NFS must be resolved through the NFS vendor.
5. Re: Ethernet Network Adapter - NetBIOS Interface Network Route should be set to Net BT. The NetBIOS Interface

APPENDIX D
RAPID PROTOTYPING EQUIPMENT

RAPID
PROTOTYPING AND
MANUFACTURING INSTITUTE

RPMI Equipment

MAJOR LABORATORY EQUIPMENT

To further the deployment of rapid prototyping and manufacturing through education.

If you want to learn how to utilize RPMI's equipment, go to [training schedules](#) and register for the trainings you need.

SLA-3500

- up to 2.5 times faster than SLA-250
- improved resin characteristics
- automatic resin refill system
- software upgrades
- modular design

The SLA 3500: Big-company performance and reliability, scaled to your workgroup. The SLA 3500 delivers all the speed, resolution, and reliability of the SLA 5000 - in a more compact

With its low power requirements and long-life solid state laser, the SLA 3500 reduces cost of ownership. The automatic resin dispensing system refills the vat for you between builds -- so you spend less time on maintenance and more time working. And like all our solid imaging

The SLA 3500 delivers the same .002-inch (.05mm) layer resolution, SmartSweep performance, and Zephyr recoating technology found in the SLA 5000 -- in a smaller physical size (footprint).

SLA-250/50

The most productive member of the SLA-250 line is the Series 50. A potent combination of power and speed, this machine integrates productivity-enhancing components to deliver a

- Interchangeable vat for rapid and easy resin exchange
- Multiple polymers available from 3D Systems to support a wide range of applications
- Revolutionary Zephyr™ Recoating System
- Ideal for 3D Systems' QuickCast™ method for investment casting applications
- Easily builds multiple identical or unique parts simultaneously
- Unattended build operation
- Minimal facility requirements

CMM PFx-5

MicroValPFx--The Personal Flexible Gage For Any Measurement Need. Its large measuring range of 457 mm X 508mm X 406 mm is 50% larger than other systems in its class. Advanced volumetric performance makes the MicroVal PFx one of the most accurate measuring machines in the world. The MicroValPFx combines the award-winning MicroVal design with an

Surveyor 3D Laser Digitizer Systems

Laser Design Inc makes the Surveyor 3D Laser Digitizing Systems in many distinct versions for every application size from scanning huge automotive parts to inspecting minute electronic components, and to fit every budget from large multinational corporations to small businesses. All our systems offer precision measurement and data editing capabilities with accuracies of up

ACTUA 2100

The Actua 2100: Rapid Concept Modeling Now, with the Actua™ 2100 from 3D systems, a designer can produce a 3-dimensional model as easily as a plot or print. Elegantly packaged to

- Cut Design Time, Increase Design Quality
- Allegro Software Makes Model Building Simple
- Continuous Build, No Post-Processing
- Simple, Reliable Everyday Operation
- Efficiency and Economy-A Winning Combination
- Raster Action Speeds Complex Parts
- Office Environment-Friendly

FDM 1650

This system was developed for the final design and prototyping phase of product development. Using our exclusive Fused Deposition Modeling technology, the FDM1650 lets you turn a design concept into a prototype. The fast, precise bench top system generates three-dimensional prototypes from 3D CAD software data. You can test the prototypes for fit and form--even

- Versatile system
- Three times the throughput of its predecessor (the FDM1600)
- Multiple modeling materials
- Easy to use
- Exceptional value

Sanders Modelmaker II System

The ModelMaker II system reduces your costs and time-to-market by translating CAD designs into solid 3D models so accurate that you can go beyond concept modeling to produce tooling

Now you can put the power of rapid prototyping to work for even your most detailed, intricate, and complex parts. So now you and your customers can evaluate designs and processes -

MORGAN-PRESS

Two-zone, solid state electronic temperature control system for accuracy and wide heat range
 Three-mode digital controllers for greater accuracy with temperature indication (optional)
 Eye-level pressure gauges for clamp and injection
 Material melting cylinder with hard chrome bore
 Precision ground chrome-plated stanchion rods
 Hand-placed aluminum mold
 Temperature selection chart
 Operating controls grouped for convenience
 Heavy-duty cast base construction

Benchman 4000

Today's manufacturers face a number of challenges, from custom manufacturing to mass production. To meet these challenges, manufacturers must adopt agile manufacturing

General Features

Vibration-dampening polymer composite machine base
 Full enclosure
 Coolant ready
 Built-in chip and coolant tray
 Coolant resistant Gortite® way covers
 Precision-ground cast iron cross slide
 Linear motion system

Machine Specifications

Axis Travel

X Axis - 12" (304mm)
 X Axis with ATC - 6.75" (171)
 Y Axis - 6" (152mm)
 Z Axis - 9" (228mm)
 Z Axis (VMC-4500) - 8.25" (210mm)
 Open height - 9.5" (240mm)
 Open height with ATC - 8" (202mm)

Work Area

Table size - 19.5" x 6.25" (495mm x 158mm)
 Table load capacity - 100 lbs. (45 kg)
 Number of T-slots - three 3/8" T-slots

Spindle (VMC-4000)

Drive motor - 1hp (746 W)
 Motor type - Brushless DC
 Speed range - 0 to 5,000 RPM

Spindle nose - R8 taper
 Collet capacity - up to .875" (22mm)
 ATC collet - ER-20, .5" (12mm)
 Throat - 6.25" (158mm)

Spindle (VMC-4500)

Drive motor - 1hp (746 W)
 Motor type - High-frequency induction
 Speed range - 3,000 to 39,000 RPM
 Collet capacity - up to .375" (10mm)
 Collet - ER-16
 Throat - 6.25" (158mm)

Accuracies

Positional Accuracy - +/- .0004"
 Repeatability - 0.0002" (0.00508mm)
 Resolution - 0.00001" (0.000254mm)

Feed Motors

Feed rate - .1 to 200 ipm (2 to 5080mm/min)
 DC Servo - 24V, 50 oz. in. (35 Ncm)
 Closed Loop - 2,500 line differential encoders

Power Requirements

VMC-4000

United States - 120 VAC (+10%, -15%), 50 to 60 Hz, 15A

Dimensions

Width - 41.5" (1055mm)
 Depth - 38.0" (965mm)
 Height - 40.1" (1019mm)

Weight (approximate)

Net - 600 lbs. (273 kg)

Control Specifications

Interpolation

Full 3-axis simultaneous movement, 4th axis optional
 Simultaneous linear and circular interpolation on 3 axes
 Helical interpolation
 Circular interpolation with center point or radius input

Programming Standards

EIA RS274-D standard G & M codes
 Multiple programs possible with chaining command
 Fanuc® compatible
 CAD/CAM compatible

Programming Modes

Incremental and absolute programming
 Inch or metric programming
 Scaling, rotating, mirroring and subroutines

Programming Features

Programmed pause, dwell, chain and repeat functions
 Programmable on/off spindle motor with M codes
 Programmable spindle speed control with S codes
 Programmable clockwise and counterclockwise spindle
 Canned cycles for drilling and boring

Align/homing functions
 Tool length offsets for 99 tools
 Cutter compensation
 Leadscrew error compensation
 Multiple coordinate systems

Operational Modes

Programmed feed rate control
 Manual cycle start and stop
 Manual override spindle speed, 0 to 150%
 Manual override feed rate, 0 to 150%
 Computer-controlled jog, go-to and traverse motion
 Operational mode: single block and continuous run
 Optional skip and stop
 Manual program pause and feedhold

System Input

Keyboard- or mouse-operated menus
 Full screen editor support with keyboard or mouse

System Feedback

Error messages
 HELP functions on screen
 Instantaneous position readout of X, Y, Z and A axes
 Real-time or simulated 3-D solid or centerline tool path verification
 Spindle load monitor

Electronic Interface

32-bit DSP motion control card
 Control Area Network (CAN) link
 Control software on 3.5" disks

Sumitomo 75 Ton Plastic Injection Molding Machine

Sumitomo Heavy Industries (S) Pte Ltd

360 , Orchard Rd , #10-04/05
 Singapore 238869
 (65) 7330294
 (65) 7330441

Van Dorn 75 ton Injection Molding Press
www.vandorn.com

COMPUTER EQUIPMENT

Hardware:

(UNIX Platforms)

One Octane Server with Risk 195 from Silicon Graphics, Inc.
 One Indigo 2 Work Station with Risk 200 from Silicon Graphics, Inc.
 One Sparc 4 Communication Server by Sun Microsystems
 Two O 2 Work Stations with Risk 175 from Silcicon Graphics, Inc.

(WINDOWS Platforms)

One PC Server with a 486DX200 processor and 64 MB of RAM
 One PC Work Station with a 486DX33 processor and 16 MB of RAM
 Two PC Work Stations with P-Pro 200 processors and 64 MB of RAM by Gateway 2000
 Two PC Work Stations with P-100 and P-200 processors and 72 and 80 MB of RAM
 Two PC Work Stations with Pentium-S processors and 16 MB of RAM
 Two PC Work Stations with Dual PII 400 MHz processors and 256 MB RAM
 Three PC Work Stations with PII 450 MHz processors and 256 MB RAM
 ONe PC Work Station with 500 MHz Alpha processor and 128 MB RAM

(Intranet/Internet Connectivity)

One T-1 Internet Connection
 16 Port Passive Ethernet Hub
 Cisco 752 ISDN Router
 One 33.6 Dial In Modem
 Four US Robotics 28.8 Modems
 Computone Terminal Server

(Input/Output)

One HP OfficeJet Pro 1150C
 One Hewelett Packard ScanJet 4C Scanner
 One Hewelet Packard Laser Printer
 One SLA Internet-Modified Camera
 One Silicon Graphics Networking Digital Camera
 One Kodak ds DC50 Digital Zoom Camera
 One Techtronix Wax Color Printer

CAD and Geometric Software:

Allegro
 AutoCAD
 CATIA
 Cimatron 10.0
 Geomagic Wrap/Shape
 IGRIP
 Imageware Surfacer 9.0

RPM ver. 8.0
MAESTRO 1.9
MiniTab Statistical Software
Pro-Engineer* ver.20
QuickSlice ver. 6.2
SDRC IDEAS --Master's Services 6.0
Solaris Works 96/97
SolidWorks98* +
Solidview 1.02/2.0/3.0
StlView
3D C-Mold Quick Fill
Dr. C Mold
3D Lightyear 1.0
BuildStation 5.0

Software:

COREL 50
COSMOS-FEA/ COSMOSM/ COSMOSWORKS
IRIX Applications ver. 6.2/6.3/6.4
LabView
Live Works-Meeting Disk 4.5
MS EXCHANGE
MS IIS
MS Front Page
MS Office 97
MS Project 98
MS Visual C++
MS Visual Basic Professional Edition
MS Visual Studio 97
PC Medic 97
PkZip
QuikCam
RP and MS Resource Guide
Virus Scan Security Suite
WebSite Professional
Windows 95/NT Workstation & Server
WsFTP_95 LE
Macromedia

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