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GROUP DECISION SUPPORT SYSTEMS (GDSS) FOR SUPPLY CHAIN MANAGEMENT (SCM)

by

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
ASP	Average Street Price
CMC	Computer Mediated Communication
CMCS	Computer Mediated Communication Systems
CPU	Central Processing Unit
CRP	Continous Replenishment Program
DM	Decision Maker
DRAM	Dynamic RAM
DSS	Decision Support Systems
EB	Electronic Brainstorming
EDI	Electronic Data Interchange
EDO	Extended Data Out
EFT	Electronic Funds Transfer
EIS	Executive Information Systems
ELECTRE	**EL**imination and (**Et**) **C**hoice **T**ranslating **Re**ality
EMS	Electronic Meeting Systems
ES	Expert Systems
ESP	Expert System Planner
FPM	Fast Page Mode
FTP	File Transfer Protocol
GDM	Group Decision Making
GDPM	Goal Directed Project Management
GDSS	Group Decision Support Systems
GS	Group Systems
GSS	Group Support Systems
GWE	Group Work Environment
HPA	High Performance Addressing
HTML	Hypertext Mark-Up Language
HTTP	Hypertext Transfer Protocol
IP	Internet Protocol
IPPC	Integrated Production Planning and Control

IR	Information Retrievel
ISCM	Integrated Supply Chain Management
ISP	Internet Server Provider
IT	Information Technology
JIT	Just In Time
KM	Knowledge Management
KPSO	Knowledge People System Organization
LAN	Local Area Network
LCD	Liquid Crystal Display
MADM	Multi Attribute Decision Making
MAUT	Multi Attribute Utility Theory
MCDM	Multi Criteria Decision Making
MCGDM	Multi Criteria Group Decision Making
MIS	Management Information Systems
MODM	Multi Objective Decision Making
MSRP	Manufacturer Suggested Retail Price
MW	Meeting Works
NGT	Nominal Group Technique
OC	Operating Cost
PC	Personal Computer
POMS	Production Operations Management Systems
PROMETHEE	**P**reference **R**anking **O**rganisation **METH**od of **E**nrichment **E**valuation
PSO	People System Organization
R&D	Research and Development
RAM	Random Access Memory
REMBRANDT	**R**atio **E**stimation in **M**agnitudes or deci-**B**ells to **R**ate **A**lternatives which are **N**on-**D**ominated
ROM	Read Only Memory
SCM	Supply Chain Management
SDRAM	Synchronous DRAM
WWW	World Wide Web

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ABSTRACT

As organizations continously seek to provide their products and services to customers faster and cheaper, managers have come to realize that they can not accomplish it alone; they hence must work on a cooperative basis in Supply Chain Management (SCM). Nowadays, many important decisions in organizations are made not only by a single individual, but also by groups of individuals. Group Decision Support Systems (GDSS) enable organizations to focus on key business activities especially in Supply Chain Management Process. In this process, from the raw material to the end customer there are two flows, which are the material flow and the information flow. These flows must be managed successfully via GDSS in SCM. In every stage of SCM, there is a selection process. Therefore, the firms may handle this selection by effectively using GDSS. In GDSS, there is a multi criteria decision aid. This aid aims to give the decision maker some tools and techniques in order to enable him to advance in solving a decision problem where several points of view must be taken into account. Therefore, Multi Criteria Decision Making (MCDM) methods have received increased attention and become a practical approach for certain types of problems in the real life.

This research describes the development of a model for the selection of laptop computers.

The purpose of this study is to apply Multiple Attribute Decision Making (MADM) methods to the selection of laptop computers for a firm (which is the procurement stage of SCM) by using GDSS. Our model consists of 279 different types of laptop computers and 86 criteria. The methods used in this study are Analytic Hierarchy Process (AHP), REMBRANDT, ELECTRE, and PROMETHEE. The following steps were carried out while applying the methods to the problem. Firstly, the hierarchy tree was created by decomposing into criteria and sub-criteria.. Secondly, the weigths for the criteria and alternatives were determined. The relevant weights were calculated using pairwise comparisons by GDSS. Finally MCDM methods were applied to this model. Programming language Java was used to implement the considered methods. The results look like similar.

Based on this model, the research provides a means whereby companies or organizations can assess the selection of activities, which are critical to their business by using GDSS.

Keywords: Group Decision Support Systems (GDSS), Supply Chain Management (SCM) Multi Criteria Decision Making (MCDM), Multiple Attribute Decision Making (MADM), AHP, REMBRANDT, ELECTRE and PROMETHEE Methods

ÖZET

Kuruluşlar, sürekli olarak kendi ürün ve hizmetlerini müşteriye daha ucuz ve hızlı sağlamanın yollarını aradıkça, yöneticiler artık bu işi yalnız başlarına yapamayacaklarını anlamışlar ve Tedarik Zincir Yönetiminde de işbirliği yaparak, çalışma gereğini duymuşlardır. Böylece, kuruluşlardaki bir çok önemli karar sadece kişiler bazında değil, aynı zamanda gruplar tarafından alınmaya başlanmıştır. Grup Karar Destek Sistemleri, kuruluşların kritik iş faaliyetlerine, özellikle Tedarik Zincir Yönetimi sürecine odaklanmasını mümkün kılarlar. Tedarik Zincir Yönetiminde, hammaddenin girişinden son kullanıcıya kadar olan süreçte malzeme ve bilgi akışı vardır. Bu süreçte malzeme ve bilgi akışları, Grup Karar Destek Sistemlerinin etkin bir şekilde kullanılmasıyla, başarılı bir şekilde yönetilebilir. Tedarik Zincir Yönetiminin her safhasında bir seçim sözkonusudur. Grup Karar Destek Sistemlerinin özünde çok kriterli karar destek araçları vardır. Çok kriterli karar destek araçları, karar vericiye bir karar probleminin çeşitli açılardan tüm yönleriyle ele alınarak incelenmesini imkan veren teknik alt yapıyı sağlarlar. Bu yüzden, Çok Kriterli Karar Verme metodları, gerçek hayatta rastlanan belirli tipteki problemlere uygulanabilir olması nedeniyle, son zamanlarda yoğun ilgi görmüştür.

Bu araştırma, laptop bilgisayar seçimi için bir modelin geliştirilmesini tasvir eder.

Bu çalışmanın amacı, Grup Karar Destek Sistemlerinin kullanılması suretiyle Çok Nitelikli (Ölçütlü) Karar Verme metodlarının, bir firmanın satın alma sürecinde laptop tipi bilgisayar seçimine uygulanmasıdır. Uygulamamızda, 279 laptop bilgisayar ve 86 kriter.bulunmaktadır. Çalışmada kullanılan metodlar AHP, REMBRANDT, PROMETHEE ve ELECTRE'dır. Bu metodlar probleme uygulanırken aşağıdaki adımlar gerçekleştirilmiştir.İlk olarak, problemin kriterler ve altkriterlere ayrıştığı bir hiyerarşi ağacı çıkarılmıştır. Müteakiben kriterlerin, ve her bir kritere göre alternatiflerin ağırlıkları belirlenmiştir. Sözkonusu ağırlıklar, Grup Karar Destek Sistemleri yardımıyla gruplar tarafından ikili kıyaslamalar yapılarak bulunmuştur. Sonuçta, ilgili metodlar bu modele uygulanmıştır. JAVA programlama dili kullanılarak ilgili metodların sonuçları bulunmuş ve her bir metod için bulunan sonuçların birbirine yakın çıktığı gözlenmiştir.

Bu model baz alındığı takdirde, bu çalışma, diğer firma ve kuruluşların, grup karar destek sistemlerini kullanarak, kendileri için kritik olan faaliyetlerin değerlendirilmesinde, bir araç olarak yol gösterici özelliğe sahiptir.

Anahtar Kelimeler: Grup Karar Destek Sistemleri, Tedarik Zinciri Yönetimi, Çok Kriterli Karar Verme,Çok Nitelikli (Ölçütlü) Karar Verme, AHP, REMBRANDT, PROMETHEE, ve ELECTRE Metodları

1. INTRODUCTION

In the rapid pace of today's business markets, it is often difficult to be able to focus on the issues and elements that should have priority. Group Decision Support Systems (GDSS) provide a framework of processes within a workshop environment that will enable your organization to focus on key business activities. It is all done within context that is customized to your unique corporate culture. Another benefit is that, the training in the methodology of obtaining these results can be replicated throughout the organization. Every time, the GDSS skills are used, your organization becomes more effective and consequently, generates more of a competitive advantage. GDSS consultants combine a unique blend of analysis, facilitation, and the domain knowledge to help cross-functional teams build commitment and consensus, solve problems, and produce guaranteed results, faster, and at a lower cost.

Business leaders spend much of their days in unproductive meetings, ones that do not result in action towards the organization's goals and objectives. Conversely, the actions taken by the organization often fail because of the lack of buy-in and commitment well-run meetings produce.

GDSS meeting participants most often tell us they left satisfied in four key ways:

1. The process used was explicit, fair, and effective. (Process Satisfaction)

2. Each and every participant will say that they were personally treated honorably. They will say they had ample opportunity to be heard and their inputs were captured and considered. (Personal Satisfaction)

3. Everyone will express they can live with the outcomes and be committed to follow-through (Outcome Satisfaction).

4. Participants declare that it was a valuable investment of their time and one of the best-run meetings they ever attended (Overall Satisfaction).

The sessions are intense, invigorating, and fun. GDSS takes responsibility for capturing and managing the knowledge throughout the process. Every session ends with the development of an action plan with clear accountabilities.

As a result of these changes, organizations find that it is no longer enough to manage their organizations.They must also be involved in the management of the network of all upstream firms that provide inputs (directly or indirectly), as well as the network of downstream firms responsible for delivery and after market service of product to the end customer. All organizations are part of one or more supply chains.

But in the supply chain management, procurement is also an important element. From the raw material to the end customer, there are two flows; these are the material flow and the information flow. These flows must be managed successfully via GDSS in SCM. In every stage of SCM, there is a selection process. Therefore, the firms handle this selection by using GDSS effectively.

In GDSS, there is a multi criteria decision aid. As its name indicates, multicriteria decision aid aims to give the decision maker some tools in order to enable him to advance in solving a decision problem where several points of view must be taken into account. The first fact which should be noted when dealing with this type of problem is that there does not exist, in general, any decision (solution, action) which is the best simultaneously from all points of view. Therefore, the word optimization does not make any sense in such a context; in contrast to the classical techniques of operations research, multicriteria methods do not yield objectively best solutions (such solutions do not exist).This is why, the word “aid” seems essential to us. The evolution of multicriteria methods illustrates this point of view perfectly. Therefore, Multi Criteria Decision Making methods have received increased attention and become as practical approach to certain classes of management problems in real life (Vincke, 1992).

The general purpose of this research is to apply Multiple Attribute Decision Making (MADM) methods to the selection of laptop computers for a firm (which is the procurement element of SCM) by using GDSS. These methods are Analytic Hierarchy Process (AHP), REMBRANDT, ELECTRE, and PROMETHEE. First, the laptop computer problem is decomposed into criteria and sub-criteria. The hierarchy tree is formed. and the alternatives are listed. Their weights are calculated using pair wise comparisons by GDSS. Finally, MADM methods are applied to this problem.

This research describes the improvement of a model for the selection of laptop computers. Based on this model, the research provides a means whereby companies or organizations can assess the selection of activities critical to their business by using GDSS.

.1. Problem

In our daily life, we always make a selection among alternatives. Since we live in a society, everyone has judgments in making a selection. We have to consider all points of view of a selection problem by taking into account of group's views. Therefore we use MCDM methods by using GDSS for a selection. In this research, a laptop computer selection for a firm will be examined by using the MADM methods.

1.2. Description of Research

This research is designed to assess a laptop selection of a firm and provides a tool in management activities in real life problems. Both qualitative and quantative data are used in the MADM methods.

1.2.1. Title

The title of the thesis study is **Group Decision Support Systems (GDSS) for Supply Chain Management (SCM)**

1.2.2. Purpose

In recent years, MCDM methods have come into prominence; its tools and techniques have been developed and subsequently applied to a myriad of decision problems, which are mainly related to the industrial sector problems. With this development, it is extremely desirable for decision makers and analysts to keep abreast with the very dynamic state of the art of MCDM. The purpose of this research is to apply MADM methods to the selection of laptop computers for a firm (which is the procurement element of SCM) by using GDSS.

The research consists of the following steps:

For AHP and REMBRANDT techniques:

1. Construct the hierarchy tree
2. Identify and list the criteria and alternatives
3. Provide the weights by using pair wise comparisons.
4. Calculate the weights of criteria and alternatives
5. Evaluate the alternatives

For PROMETHEE technique:

1. Identify and list the criteria and alternatives
2. Provide the values of alternatives
3. Provide the weights, preference threshold (p), indifference threshold (q) of criteria and identify type of the criteria.
4. Calculate the ingoing and outgoing flows and the network flows
5. Evaluate the alternatives

For ELECTRE technique:

1. Identify and list the criteria and alternatives
2. Provide the values of alternatives
3. Provide the weights, preference threshold (p), indifference threshold (q) and veto thresholds (v) of criteria
4. Calculate the concordance, discordance, credibility matrices for alternatives
5. Find the descending and ascending preorders and the final preorder,
6. Evaluate the alternatives.

1.3. Research Methods

1.3.1. Literature Review

Literature review related to GDSS, SCM and MCDM contains numerous researches, studies, books, articles, and papers in many libraries, namely, Boğaziçi University, Yeditepe university, etc. The literature review will be explained in chapter 2.

1.3.2. Internet Survey

The internet survey included different databases such as electronic libraries, e-journals, dissertation abstracts and university libraries. In each of these sources, the following topics were examined for relevant literature as the keywords:

1. Decision
2. Decision Making
3. Multi Criteria Decision Making
4. Decision Support systems
5. Group Decision Support Systems
6. Supply Chain Management

7. MCDM Techniques
8. Analytic hierarchy Process (AHP)
9. REMBRANDT Method
10. PROMETHEE Method
11. ELECTRE Method
12. Computers
13. Laptop computers

Contacts with researchers, academicians, and TOYOTA firm were established. The research was executed in the Department of Management of Information Systems, Boğaziçi University. MIS personnel supported the research as both experts and participants.

1.3.3. Questionnaire

In this research, the data utilized to develop the MADM methods were gathered from experts in TOYOTA firm and in Department of Management Information Systems of Boğaziçi University and the journals related to the computer.

The population of the survey in this study consist of people that work at various stages of procurement cycle in TOYOTA firm and Management Information Systems Department personnel of Boğaziçi University who participated in every phase of the research.

At the end of the literature survey and interviews, we identified the criteria for selecting laptop computer for a firm. The questionnaire is prepared according to Saaty's scale. It has two-sided judgments with pair wise comparisons of factors with respect to a certain goal. The questionnaire shows a numerical comparison as *equal* corresponds to 1, *moderate* to 3, *strong* to 5, *very strong* to 7, and *extreme* to 9. Using pair wise comparisons, the relative importance of one criterion over another can be expressed. Since there are a lot of criterion and alternatives, the weights are calculated by using Java program. Both quantative and qualitative criteria can be compared with each other by using informed judgments driven from weights and priorities.

Interviews, questionnaires were used for data gathering. The data were collected during two months (October-November 2001).

To ensure reliability and validity of the survey instrument, several actions were taken. First, the respondents are chosen among experienced personnel. Second, interviews and questionnaires are used to provide concise, clearly defined and well-constructed questions.

Third, inconsistency in the ratios of the respondent answers is calculated. If the inconsistency ratio is less than 0.1, the answers are assumed to be consistent. But during the questionnaire phase, every respondent's evaluation matrix inconsistency ratio was 0.1. Otherwise, they are asked to reevaluate their values.

Since GDSS were used in this research, Goal Directed Project Management (GDPM) methodology was applied in this research. GDPM is a project management methodology developed by E. Andersen, K.V. Grude, and T Haug (1995). This method contains procedures and tools, which support project management. GDPM shows how to organize resources in an organizationally complex situation. In addition, it shows how to set goals and break each goal down into controllable intermediate goal and how to divide work tasks into many parts. This method helps decomposing criteria and sub-criteria and also helps the construction of the hierarchy tree of the model.

1.3.4. Software

Programming language Java is used for implementing the models of Analytic Hierarchy Process (AHP), REMBRANDT, ELECTRE, PROMETHEE. In addition to this, microsoft office tools (such as Excel, Word, Power-point and Access) are widely used in writing the thesis and preparing the presentations of the study.

2. LITERATURE REVIEW

2.1. SUPPLY CHAIN MANAGEMENT

Supply Chain Management has received increased attention during the past five to ten years (Carr and Smeltzer, 1999). Today's ever-changing markets, maintaining an efficient and flexible supply chain is critical for every enterprise. In order to retain and strengthen their competitive edge in the market, organizations need to coordinate and integrate all their business operations right from raw materials purchase stage to product distribution stage with sustainability consideration (Zhou et al., 2000).

2.1.1. The Definition of The Supply Chain Management (SCM)

Various definitions of a supply chain have been offered in the past several years. Handfield and Nichols (1999) defined supply chain as all activities associated with the flow and transformation of goods from the raw materials stage (extraction) to the end user, as well as the associated information flows. Material and information flow both up and down the supply chain.

Lummus and Vokurka (1999) defined the supply chain as the network of entities through which material flows. Those entities may include suppliers, carriers, manufacturing sites, distribution centers, retailers and customers.

Supply Chain is an integration of manufacturing process where raw materials are converted into final products, then delivered to customers (Beamon, 1998).

Lummus and Alber (1997) define supply chain as, "The network of entities through which material flows. Those entities include suppliers, carriers, manufacturing sites, distribution centers, retailers, and customers".

A supply chain is the set of processes that plan, source, produce and deliver products or services to customers through the management of the flow of materials, information and cash. The notion of a single chain however can be misleading since modern organizations are more often a network of processing nodes; the analogy of a chain directly highlights the dependency of each link on every other link (Franciose, 1995).

The supply chain has been defined as the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer (Vrijhoef and Koskela, 2000).

A supply chain has been conceptualized as "a system whose constituent parts include materials supplies, production facilities, distribution services and customers linked via the feed-forward flow of materials and the feedback flow of information" (Khalfan et.al. 2001).

SCM is network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumers (Akintoye et al., 2000).

The supply chain can be stated as: all the activities in delivering a product from raw materials through to the customer including sourcing raw materials and parts, manufacturing and assembly, warehousing, and inventory tracking, order entry and order management, distribution across all channels, delivery to the customer, and the information system necessary to monitor all this activities (Arslan, 1999).

Monczka and Morgan (1997) defined the term "Integrated Supply Chain Management" as an integrating philosophy to manage all the processes that are needed to provide the customer with value in a horizontal way.

Supply chain management (SCM) is the term used to describe the management of materials, money and information across the entire supply chain, from suppliers to component producers to final assemblers to distribution (warehouses and retailers), and ultimately to the consumer (Pyke et al., 2001).

The supply chain involves all activities associated with the flow and transformation of goods from the raw material stage, through to the end user, as well as the associated information flows. SCM is the integration of these activities through improved inter and intrafirm relationships to achieve sustainable competitive advantage (Ellinger, 2000).

From these definitions it can be deduced that Supply Chain Management (SCM) is the integrating and coordination of all activities consisting of delivering a product from raw material through to the customer including sourcing raw materials and parts, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, delivery to the customer and the information systems necessary to show all of these activities (Lummus and Vokurka, 1999).

Supply Chain Management is the integration of business processes that also involves the logistics processes. From this view, it is obvious that Supply Chain Management includes more function than logistics. "It is clear that there is a need for some level of coordination of activities and processes those goes beyond logistics. New product development is perhaps the clearest example of this since all aspects of business ideally should be involved, including marketing concept, research and development for the actual formulation, manufacturing and logistics for their respective capabilities, and finance for their funding. In addition to these internal functions there is a need to include external organization in the product development process in order to reduce time -to-market on new product introductions. Early supplier involvement in the product development process is important and, in some cases, second tier suppliers. Further, consumer and customer involvement is necessary. It should be apparent logistics is never going to own the product development process or the customer for that matter." (Cooper et al., 1997).

Handfield and Nichols (1999) define the term supply chain management as the integration of all activities -that are associated with the flow and transformation of goods from the raw materials stage (extraction), through to the end user, as well as the associated information flows- through improved supply chain relationships, to achieve a sustainable competitive advantage. Material and information flow both up and down the supply chain.

Supply Chain Management, coordinates and integrates all of the activities. It encompasses and links all of the partners in the chain. In addition to the departments within the organization, these partners include vendors, carriers, and information system providers.

Supply Chain Management is about getting a smooth and efficient flow from raw materials to finished goods in the customer's hands. It is a concept, which is increasingly replacing traditional fragmented management approaches to buying, storing and moving goods.

In the past, marketing, distribution, planning, manufacturing, and the purchasing organizations along the supply chain operated independently. Each organization has its own objectives and these are often conflicting. Marketing's objective of high customer service and maximum sales dollars conflict with manufacturing and distribution goals. Many manufacturing operations are designed to maximize throughput and lower costs with little consideration for the impact on inventory levels and distribution capabilities. Purchasing contracts are often negotiated with very little information beyond historical buying patterns. The result of these factors is that there is not a single, integrated plan for the organization there were as many plans as businesses. There is a need for a mechanism through which these different functions can be integrated together. Supply Chain Management is a strategy through which such integration can be achieved.

Supply Chain Management will not guarantee prosperity; but it is fundamental to sustained competitive success. Its application depends on effective co-operation by all trading partners, many of whom do business with their customers' and suppliers' competitors. Successful Supply Chain Management is about doing most things in simple, standard ways, which are open to all and have widespread adoption. Effective Supply Chain Management requires that a critical mass of customers, suppliers and competitors are willing and able to manage their logistical processes in a common, standard way. Being the best company means applying these methods more quickly, simply and more reliably than the competitors. Supply Chain Management is the process of optimizing a company's internal practices, as well as the company's interaction with suppliers and customers, in order to bring products to market more efficiently.

Supply chain differs from classical materials and manufacturing in four respects (Carr and Smeltzer, 1999).

1. The supply chain is viewed as a single entity rather than fragmented;
2. It calls for and depends on strategic decision-making;
3. Inventory is viewed from a different perspective;
4. Integration rather than interface is required.

2.1.2. History of the Supply Chain Management

Historically, supply chain has focused on moving goods from manufacturer to distributor to retail store. The process was "push", where goods were shipped to store shelves with little knowledge of what consumers wanted to buy. It was a seller's market. Today, technology allows consumers to actively participate in the supply chain, actually "pulling" goods to meet their needs. It is a buyer's market (Swartz, 2000).

Supply chain management used to be simple compared to what it is today. Manufacturers sold to wholesalers or directly to retailers. Salespeople called on their supply chain customers and wrote orders. Or, retailers called in their orders or sent them by mail. This low-tech supply chain started to die out in the 1980s and was almost extinct by the mid-1990s (Levy and Grewal, 2000).

In the 1950s and 1960s, most manufacturers emphasized mass production to minimize unit production cost as the primary operations strategy, with little product or process flexibility. New product development was slow and relied exclusively on in-house technology and capacity. Bottleneck' operations were cushioned with inventory to maintain a balanced line flow, resulting in huge investment in work in process (WIP) inventory. Sharing technology and expertise with customers or suppliers was considered too risky and unacceptable and little emphasis appears to have been placed on cooperative and strategic buyer-supplier partnership. The purchasing function was generally regarded as being a service to production, and managers paid limited attention to issues concerned with purchasing (Tan, 2001).

Metz describes the evolution of Supply Chain Management in four stages (Metz, 1998). It begins with Physical Distribution Management. The second stage is Logistics stage, the third is Integrated Supply Chain Management stage, and the last stage is Super-Supply Chain Management.

Physical Distribution Management integrated warehousing and the transportation functions, providing inventory-reduction benefits from the use of faster, more frequent and especially, more reliable transportation. Shorter order response times via faster warehouse handling and faster transportation lessened the length of the forecast period, thereby increasing the accuracy of forecasts. Physical Distribution Management was enabled by improved data communications between the different levels of warehouses (plant, regional distribution center, and local distribution center) and the more complex analyses (for example, total warehouse-transportation costs, optimization of the transportation/ warehouse network).

The second phase in Supply Chain Management's development, the "Logistics stage", saw the addition of the manufacturing, procurement, and order management functions. This was aided by electronic data interchange, worldwide communications, and the growing availability of computers to store data and perform analyses.

The third phase is the "Integrated Supply Chain Management stage." To the lengthening chain of functions being integrated, suppliers were added at one end and customers at the other. This has become a seven-function supply chain, vastly more complex than the two-function physical distribution chain. To handle this complexity, electronic data, electronic

funds transfer; higher bandwidth communications, and computerized decision-support systems for planning and for execution are used. Training is a key component, too.
The next phase of Supply Chain Management, "Super-Supply Chain Management" will incorporate more functions such as product development, marketing, and customer service. It will be enabled by even more advanced communications, better and user friendlier computerized decision support systems, and increased training.
In the 1970s, Manufacturing Resource Planning was introduced and managers realized the impact of huge WIP on manufacturing cost, quality, and new product development and delivery lead-time. Manufacturers resorted to new materials management concepts to improve performance within the and four walls' of the company. The intense global competition in the 1980s forced world-class organizations to offer low cost, high quality and reliable products with greater design flexibility. Manufacturers utilized just in time (JIT) and other management initiatives to improve manufacturing efficiency and cycle time. In the fast-paced JIT manufacturing environment with little inventory to cushion production or scheduling problems, manufacturers began to realize the potential benefit and importance of strategic and cooperative buyer-supplier relationship. The concept of supply chain management emerged as manufacturers experimented with strategic partnerships with their immediate suppliers. In addition to the procurement professionals, experts in transportation and logistics carried the concept of materials management a step further to incorporate the physical distribution and transportation functions, resulting in the integrated logistics concept, also known as supply chain management.
The evolution of supply chain management continued into the 1990s as organizations further extended best practice in managing corporate resources to include strategic suppliers and the logistics function in the value chain. Supplier efficiency was broadened to include more sophisticated reconciliation of cost and quality considerations. Instead of duplicating non-value-adding activities, such as receiving inspection, manufacturers trusted suppliers' quality control by purchasing only from a handful of qualified or certified suppliers. More recently, many manufacturers and retailers have embraced the concept of supply chain management to improve efficiency across the value chain. Manufacturers now commonly exploit supplier strengths and technology in support of new product development and retailers seamlessly integrate their physical distribution function with transportation partners to achieve direct store delivery or cross docking without the need

for receiving inspection. A key facilitating mechanism in the evolution of supply chain management is a customer-focus corporate vision, which drives a change throughout a firm's internal and external linkages (Tan, 2001).

As a result of these changes and developments, managers now find that it is no longer enough to manage their organizations. They must also be involved in the management of the network of all upstream firms that provide inputs (directly or indirectly), as well as the network of downstream firms responsible for delivery and after-market service of the product to the end customer (Handfield and Nichols, 1999).

2.1.3. The aim of the supply chain management

SCM aims to integrate the activities of an entire set of organizations from procurement of material and product components to deliver completed products to the final customer. These activities refer to marketing-dominated areas such as new product development, customer relationship management and/or customer service management. Consequently, SCM leads to improvements in channel performance among all channel members and not solely within the focal firm (Alvarado and Kotzab, 2001).

2.1.4. The basic generic principles relating to a supply chain system

The end-user focus, i.e. the customer at the end of the chain, is the source of all income for the entire system. The structural make-up of the chain con-sits of vertical boundaries denoted by some entity such as a company's sphere of opera-ton or a physical break in the process. The second structural consideration is the horizontal boundaries, or channels of product and information flow, which run in parallel. These horizontal channels may emerge due distinct product streams driven by different end-user requirements. The channels should not, theoretically, compete with one another within the same supply chain system (Beesley, 1996).

The vertical and horizontal structure, by definition, as a part of a single supply chain system must have interfaces between the operational entities. These interfaces identify the concept of some form of relationship, whether internal or external. The structure and the infrastructure relationships within the supply chain guide the principle relating to how resources are used,

namely the factors of production and the positioning of inventory. The same structural and infrastructural features also determine how the supply chain system may respond to end-user demand. This is a feature of performance of the total system, and the principle of demand dynamics has to be recognized as a generic phenomenon, which influences system performance. At this point we shall focus on the six generic principles identified and understand how a time-based approach relates to these concepts. If we first look at end-user focus, i.the final customer, this area has been subject a great deal of attention through the idea quick response in the retail environment and that of just-in-time (JIT) in the manufacturing arena. The value of time as a part of the marketing mix is well understood and, as markets become more intensely competitive, the time factor becomes more critical. End customers demand speed and accuracy of delivery; they know that if they have to wait they can go elsewhere. They demand variety and choice, which require a time-based capability to supply; for example, retailers today hold minimal stock so that they can maximize the product range held under one roof. To offer a good service, fast, accurate replenishment is required. These are all well under stood concepts which can offer competitive advantage. However, some of the features of delivery system at the end of the supply chain are today just order qualifiers and not order winners. Customers do not expect to have to pay more for speed and variety; all retailers offer this (Beesley, 1996).

Competitiveness has to come from some-thing holistic about the total supply chain system rather than just what the company entity at the end of the supply chain can offer. The forcing of stock up the supply chain is a classic case in point. The need for JIT at the front end of the supply chain cannot be met by forcing stock up the chain and thereby increasing costs and constraining responsiveness. Taking this JIT stock requirement as an example, the structural make-up of the supply chain will determine where the stock will lie. If there is a general lack of trust between the operational entities in the chain, stock will be widespread throughout the system. If, however, the use of resources and the positioning of inventory are determined in a total system context through good communication and mutual trust, then the supply chain capability can be optimally tuned to the needs of the end user. The compounding factor that gives weight to taking a holistic view of the supply chain is that of demand dynamics (Beesley, 1996).

The principles that are generic to a supply chain system need to be recognized and managed so that the total system can be optimized. There are, however, a number of key issues associated with achieving optimization: first, the idea of end-user focus is obvious and yet, for example, a commodity supplier at the end of the supply chain may have very little concern for what is happening, which is usually compounded by a total lack of visibility. The issues relating to the supply chain structure in terms of company boundaries and product/customer-focused channels add further complications. Companies divide and rule through outsourcing and make/buy decisions, so that control (internal to the company) and competence are enhanced. Different channels of production and distribution are formulated to serve specific market needs. These approaches inevitably lead to a complex web, which constitutes the supply chain, and this demands bonding of intercompany relationships for it to function efficiently. The concept of partnership has rightly attracted much attention for these reasons; however, there are many skeptics who question the concept in terms of its true ability to deliver what is required in a holistic supply chain context. A time-based approach is a way of gaining a common focus for all of the contributors involved within the supply chain. It cuts across a number of commercially sensitive issues, such as costs and profit margins, and it spans company and supply chain (i.e. vertical) boundaries. How can this common, time-based focus be achieved? How can it pull together all of the key issues such as customer service, responsiveness and the use of inventory? Where do we start and how? The starting point should, logically, be when the product is designed, because ultimately competitiveness may depend on whether the product is designed for ease of logistics management in the broad areas of supply, manufacturing, distribution and the actual use of the product (Beesley, 1996).

2.1.5. Supply Chain Management Philosophy

According to Chandra and Kumar (2000) Supply Chain Management philosophy can be composed of the following items.

2.1.5.1. Flexible Organizations

A flexible organization of a firm supports plant and distribution networks by achieving operational efficiency through quick line changeovers, as well as savings realized as a result of avoiding back hauling and enhanced product realization. As firms move toward supply chain excellence, they are concerned with both internal and external efficiencies. Investments in plant and distribution equipment are important to maintain an agile organization in a supply chain.

2.1.5.2. Organizational Relationships

Strategic alliances and partnerships are crucial to the success of a supply chain. Firms are encouraged to focus their attention on the entire supply chain and reduce the number of suppliers that they have to deal with. Many firms have developed preferred supplier programs as well as core transport carriers to ensure that a quality product is received where and when it is needed. A successful strategic alliance or a partnership must be based on extreme trust, loyalty, positive sum game (a win-win relationship), cross functional teams, sharing common goals and cooperation that includes willingness to assist, and positive negotiations based on fairness.

2.1.5.3. Total Supply Chain Coordination

It is important to employ cross-channel coordination when sharing some of common resources among different supply chains. This coordination allows supply chains in a company to integrate with each other. Creating supply chain value is important for successful coordination. The most important single factor in creating supply chain value is the ability to predict or forecast demand. The goal for total coordination is to be demand driven and not lot size driven. This implies that suppliers should supply products according to demand and not lot quotas. In the past, forecasting was done primarily utilizing historical data. Firms are moving away from this method and beginning to use point of sale data, which tell them exactly how much was purchased during a certain time frame.

2.1.5.4. Improved Communications

Uncertainty and inventory levels are lowered through improved communications "within" and "between" supply chain constituents. A successful customer vendor relationship is built by exchanging information pertaining to product development for new products, product improvements, costs, demand schedules and materials and supplies needed to meet production schedules.

2.1.5.5. Outsourcing Non-core competencies

Outsourcing will continue to be important for having a cost effective business. Many firms are currently outsourcing the distribution process. They are able to track all deliveries through a third party provider.

2.1.5.6. Inventory Management

In the past, carrying inventory in stock was a normal business practice to guard against risk of unfulfilled demand. Today, many firms find that holding inventory is costly and so they try to push inventory on to someone else in the supply chain. Some firms are demanding that the manufacturer deliver inventory to private customer warehouses more frequently and in smaller lots. Some important supply chain inventory issues are: shorter delivery times, just in time (JIT), point of sales data, vendor managed inventory and consignment inventory. For example, in order to utilize a JIT system, shorter delivery times are needed and point of sale data are required to know which products are to be replenished quickly. Information sharing is critical in resolving these issues.

2.1.5.7. Cost Control

It is typical in many firms that the "operation" function desires improved product forecasts and longer lead-times. On the other hand, the "sales and marketing" function desires more inventories to alleviate the potential for stock-out. These demands lead to enhanced production capacity, thus creating excess inventory and consequently higher production costs.

Both functions blame this phenomenon on the current process. These activities pull efforts away from doing the basics well, which include sharing information among functions and concentrating on demand management (Chandra and Kumar, 2000). This phenomenon is described next with the help of the "acceleration principle" a strategy often utilized for solving supply chain problems.

2.1.6. The Types of Supply Chains

According to Metz (1998) supply chains can be divided into two categories, which are known as single-staged and multi-stage supply chains.

1.The single-stage supply chains

A single-stage supply chain. can be shown as in Figure 2.1. Every company has its own supply chain according to its service area. Customers and suppliers are crucial elements of any supply chain formation. "The single-stage supply chain typically found in a single company. It corporates the material flow functions of receiving raw material or sub-assemblies, manufacturing, distributing, and delivering. It has many information-processing and decision-making functions, reflected in the many information-flow lines." (Metz, 1998).

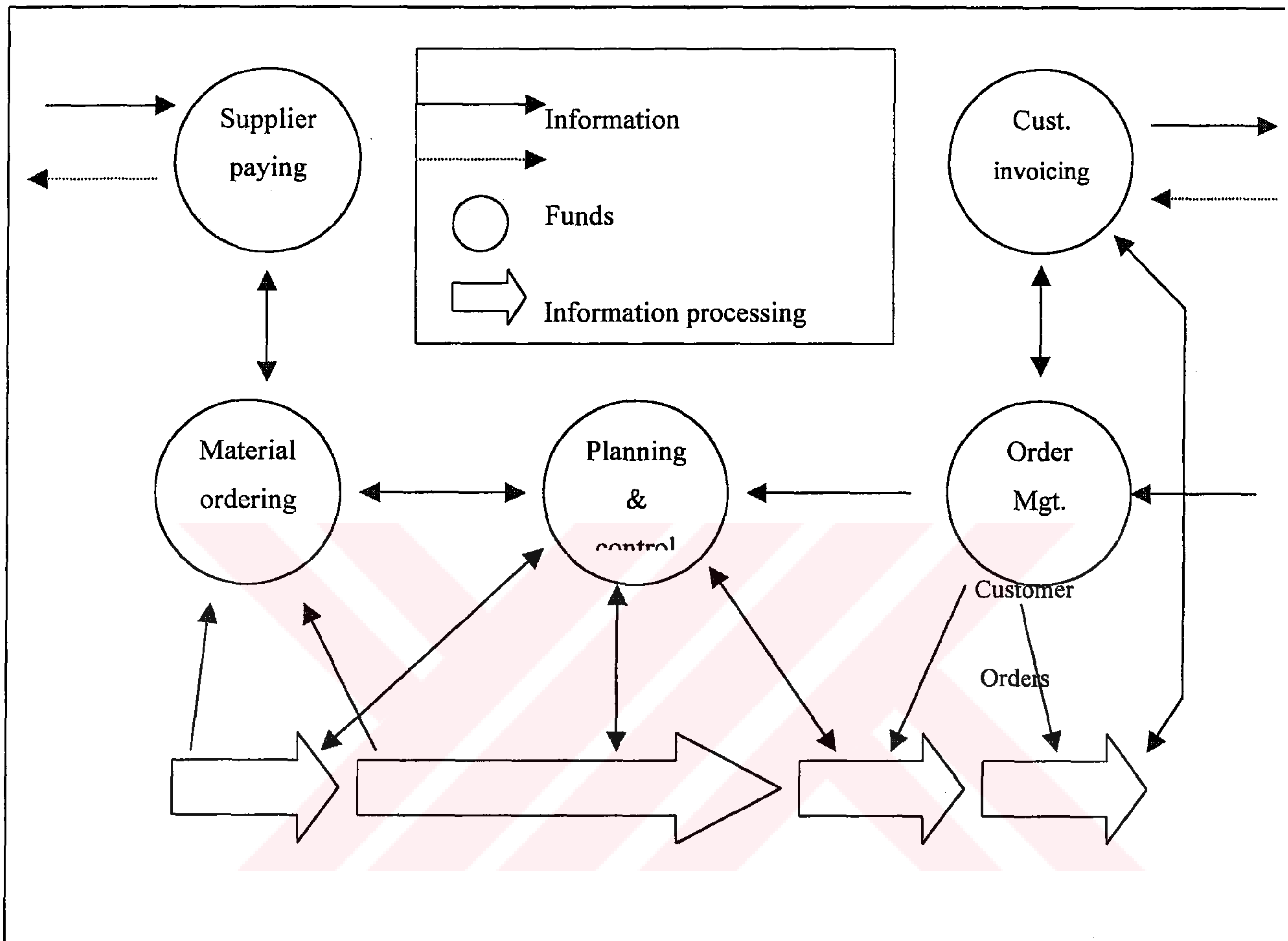

Figure 2.1. Single-Stage Supply Chain (Metz, 1998)

2.The multi-stage supply chains

A multi-stage supply chain is illustrated in Figure 2.2. Multi-stage supply chains are series of linked suppliers and customers; every customer in turn a supplier to the next downstream organization until a finished product reaches the ultimate end user. In a multi-stage supply chain departmental roles or processes in a single-stage are implemented by different firms. One firm is the supplier, the other is the producer and one another is the retailer. The flows of material, information and the funds need coordination between firms. Multi-Stage Supply Chains are typically multi-company supply chains, but they are basically multiple replications of the single-stage supply chain (Metz, 1998).

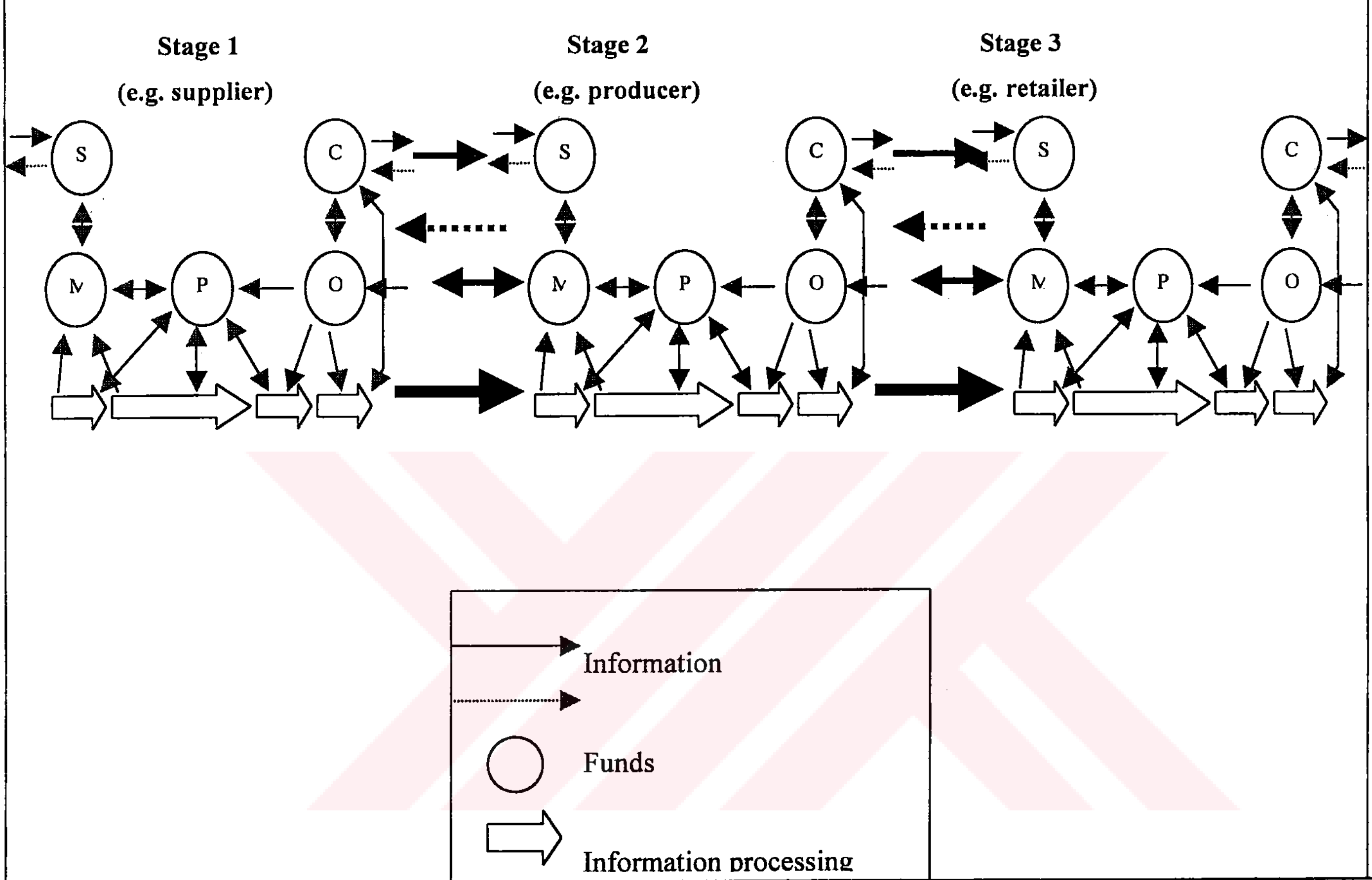

Figure 2.2. Multi-Stage Supply Chain (Metz,1998)

2.1.7. Integrated Supply Chain Model

All organizations are part of one or more supply chains. Whether a company sells directly to the end customer, it provides a service, manufactures a product, or extracts material from the earth; it can be characterized within the context of its supply chain. However, three major developments in global markets and technologies have brought supply chain management to the forefront of management's attention.

1. The information revolution

2. Customer demands in areas of product and service cost, quality, delivery, technology, and cycle time brought about by increased global competition.

3. The emergence of new forms of interorganizational relationships.

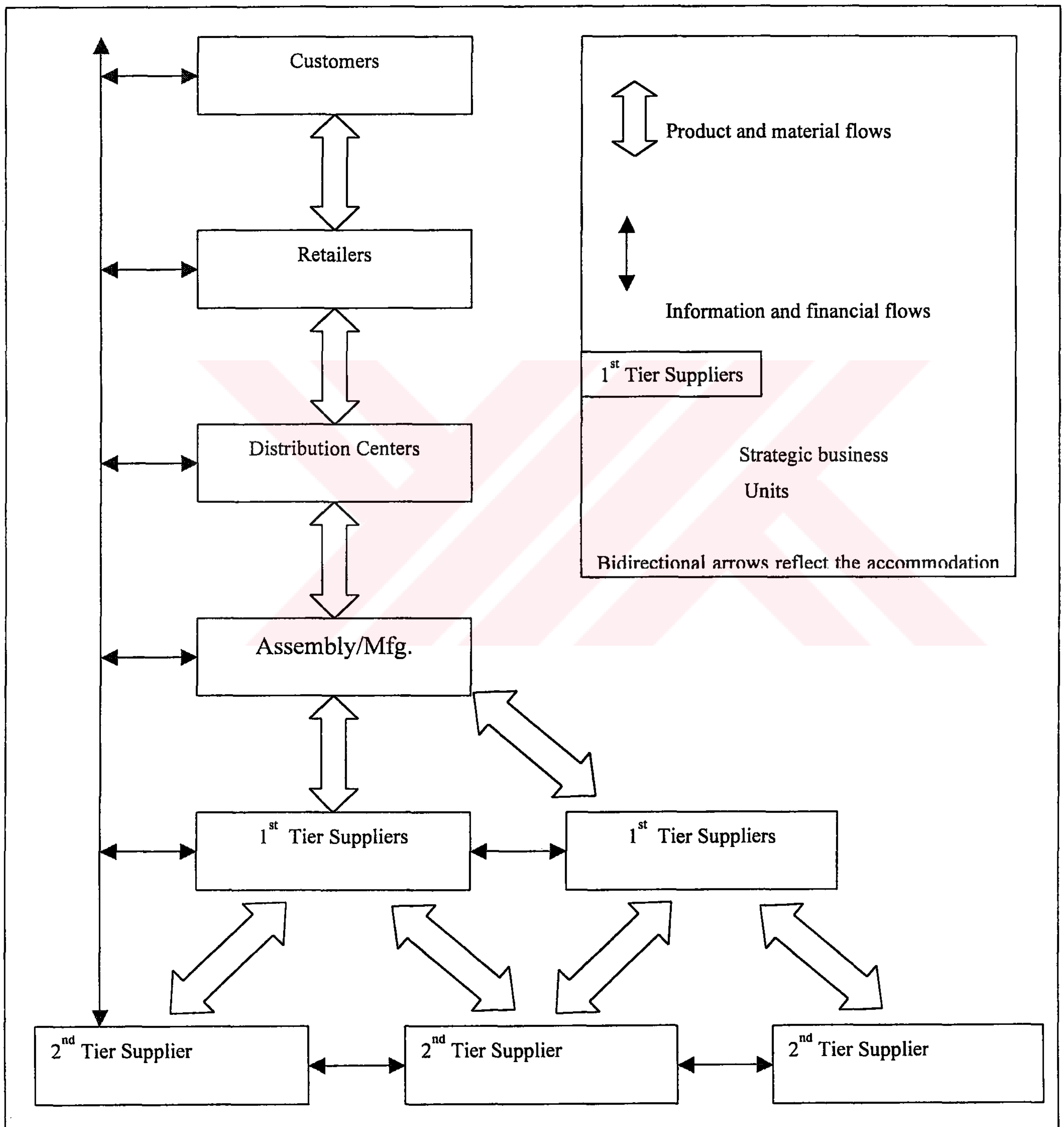

Figure 2.3.. Integrated supply chain model. (Handfield and Nichols, 1999)

2.1.8. Features of the Supply chain Management

According to Shin et al. (2000) Supply Chain Management has four basic characteristics.

2.1.8.1 Long-term relationship or partnership

An extended planning horizon is an important feature of the SCM since each participant expects the relationship to continue for a considerable amount of time. A close relationship means that channel participants share the risks and rewards and have willingness to maintain the relationship over the long term. Companies will gain benefits by placing a larger volume of business with fewer suppliers using long-term contracts. Furthermore, through a well-developed long-term relationship, a supplier becomes part of a well-managed supply chain.

2.1.8.2. Supplier involvement in product development

Supplier involvement is a critical aspect of SMO. For example, before initial prototyping begins, Toyota invites the suppliers to their product design meetings. The suppliers not only design the components but also help develop the new vehicle's concept. First-tier suppliers are treated as long-term partners. These partners invest in developing a variety of parts and present all the alternatives to Toyota before Toyota decides on its own vehicle concepts. Early supplier involvement is important in the product development process to reduce the time-to-market on new product introduction.

2.1.8.3. Reduced number of suppliers

Reduction of the supplier base is a unique characteristic of contemporary buyer-supplier relationship. Many firms have discarded the traditional practice of using several sources of supply in favor of a drastic reduction in sources of supply. Several important factors have caused the current shift to single sourcing or a reduced supplier base. First, multiple sourcing prevents suppliers from achieving the economies of scale based on order volume and learning curve. Second, the multiple supplier system can be more expensive than a single supplier system. For instance, managing a large number of suppliers for a particular item directly increases costs, including the labor and order processing costs to manage multiple-source inventories. Third, a reduced supplier base helps eliminate mistrust between buyers and suppliers due to lack of communication.

2.1.8.4. Quality performance is the number one priority in selecting suppliers

Quality has always been one of the most important performance criteria even with a conventional purchasing strategy. Many studies emphasizing a 'quality focus' of the supply management are also conceptual studies. The basic arguments of these studies are

1. Supplier quality is a critical determinant for overall product quality and costs,

2 Information of the suppliers' quality control system and quality performance helps buyers to select the right price level of the components,

3. A close supplier–buyer relationship is a requisite of information sharing. The impact of Total Quality Management (TQM) practices in the supply chain on the quality performance of suppliers using both regression and Data Envelopment Analysis. TQM practices are measured by such a variety of constructs as top management support, product, service design, supplier quality management, quality data and reporting.

2.1.9. Supply Chain Management A framework For Analysis

As noted before, supply chain network can be a complex web of systems, sub-systems, operations, activities and their relationships to one another, belonging to its various members, namely, suppliers, carriers, manufacturing plants, distribution centers, retailers and consumers.

Production operations management systems (POMS) manage functional components, such as demand and production functions of individual members of the supply chain enterprise. These also deal with the management of resources (inputs) and the distribution of finished goods and services to customers (outputs). Operations signify the production of goods and services, the set of value-added activities that transform inputs into outputs. The supply chain as a special class of network offers unique and creative ways of planning and management of complex interrelated systems. There is realization among its members that designing and implementing various sub-systems of POMS, such as materials planning, inventory management, capacity planning, logistics and production systems utilizing supply chain philosophy, will lead to overall improvement in enterprise productivity.

Integrated production planning and control (IPPC) systems assume the role of coordinator of demand and production functions. IPPC is a combination of philosophies, concepts and tools and techniques, to manage deviations in expectations of the demand and supply functions of a productive system. It is an integrated material-flow based information system, whose planning and control are based on feedback loop of control theory. Main approaches to IPPC are push, pull and synchronous flow production systems.

The supply chain framework elements are categorized by Chandra and Kumar (2000) as follows:

1. Goals
2. Objectives
3. Modelling principles
4. Developing coordinated strategies
5. Implementation

1. Goals

Supply chain goals are mutually agreed upon between members in a spirit of cooperation. Members negotiate and compromise with each other, in order to arrive at acceptable goals. Goals for the supply chain are set at two levels. Members synergize their activities and resources toward accomplishing common goals for the supply chain as a group that aim to benefit all, and not just a few among the group. In addition, members may pursue individual goals that reflect their organizational values and expectations. However, the two sets of goals must be coordinated in order to be effective performance measures for the supply chain. This may require tuning individual goals of members such that common supply chain goals can be met.

2. Objectives

Supply chain objectives directly support its stated goals as such; they are derived from published goals. For example, a common manufacturing supply chain goal can be to enhance revenue through eliminating or alleviating bottleneck operations in the system. Supply chain objectives that directly support this goal can be defined as:

a. Increase through-put;

b. Reduce cycle time;

c. Reduce inventory at different stages (raw materials- work-in-process-finished goods).

As can be seen, these objectives are complementary to each other. For example, a primary objective of increased throughput in the supply chain must be supported by a secondary objective to reduce cycle time. A reduction in processing time and set-up time will allow smaller batches to be processed faster, thereby lessening congestion in the system and registering shorter cycle time. This will also create increased through-put, and consequently, a

Higher revenue stream in the supply chain. As a result of this improvement in the supply chain, the tertiary objective of reduced inventory at different stages will not have to wait for availability of orations for further processing (Chandra and Kumar, 2000).

3. Modelling Principles

In general, the principles are described below:

Principle No. 1: Reducing the influence of lead-time variability in the productive system.

The influence of lead-time can be felt in the supply chain at any and/or all stages of its life cycle. The transformation of product through various stages in its life cycle bring out cycle time in its various manifestations, such as set-up time, queue time, wait time and idle time. One of the primary challenges in modelling waste management in the supply chain is to reduce variability of these cycle time elements. This is mainly accomplished by designing coordination mechanisms through sharing of information in the form of demand schedules, capacity production plans etc.

Principle No. 2.: Reducing the influence of inventory variability at different stages and locations in the supply chain.

Inventory variability poses a serious challenge in the management of a supply chain. This is crucial, because the material flow in a supply chain takes on many forms through its life cycle and thus assumes various inventory classifications.

Principle No.3.: Reducing the influence of batching effects variability in the productive system.

This principle prescribes the relationship between lot size and lead-time should be closely managed in a manufacturing supply chain. Two types of effects that emerge from this relationship are batching effect and saturation effect.

Batching Effect: The rationale behind this effect is that an increase in lot size should also increase lead-time. For example, a batch of one unit can immediately move to the next operation as soon as it's processing is complete. However, a batch of five units does not move until all five units are completed.

Saturation Effect: The rationale behind this effect is that saturation effect works conversely to the batching effect. That is, when lot sizes decrease, and set-up is not reduced, lead-time will eventually increase. The reason is that, if demand stays the same, as lot sizes are reduced there will be more lots in the shop. This results in more time spent on set-ups and less time available for processing. As a result, demand becomes a relatively larger proportion of available capacity and congestion increases.

Principle No.4.: Reducing the influence of variability due to bottleneck operations in the supply chain.

The rationale behind this principle is that, rather than balancing capacities, the flow of product through the system should be balanced. That is, the modelling of waste management should be designed to control throughput and work-in-process inventory simultaneously. This will require converting a bottleneck activity to non-bottleneck activity in the supply chain. We can achieve this by creating buffers due to time, inventory, lead-time, etc. so as to allow the bottleneck activity to be synchronized with the succeeding non-bottleneck activity (Chandra and Kumar, 2000).

4. Developing Coordinated Strategies

The implementation of waste management models for a manufacturing supply chain mandates cohesive strategies that support goals and objectives of the enterprise. There is a need for models that describe and implement controls of various subsystems for controlling the total supply chain system. Such a model enables developing interaction between production and marketing policies between the supply process of raw materials and the production of finished products.

The element of coordination in developing effective strategies for a manufacturing supply chain is built by incorporating planning and control function as the integration unit. For example, marketing strategies for a supply chain emphasize varying stocking policies to maintain inventory effectiveness while ensuring service levels under varying planning and control scenarios (Chandra and Kumar, 2000)

2.1.10. Strategies of SCM

According to Schönsleben (2000), Strategies of SCM are:

1.Quality:

a. Each co-producer feels responsible for the satisfaction of the end user.

b. Quality requirements are developed and improved mutually.

2. Cost:

a. All advantages of SCM are maintained. This leads generally to lower transaction costs.

b. Sharing of methods and know-how among co-producers reduce costs.

c. Each co-producer is active in its area of core competence. This yields the best possible return from the resources implemented.

3. Delivery:

a. The same logistics are necessary for all co-producers (same operational procedures, documents etc.).

b. Planning and control systems are linked for example via EDI).

c. The choice of co-producer depends with chief importance upon speed that is the co producer's contribution to short lead times.

4. Flexibility:

a. All co-producers give impetus towards product development.

b. Once again the buyers' market guarantees that the approach be robust; transaction costs are low, and replacement suppliers may be arranged relatively easily (buy decision).

5. Entrepreneurial cooperation in the logistics network:

a. All co-producers are involved in product and process development from the start.

b. All co-producers are involved in planning and control.

2.1.11. Supply Chain Performance Measures

An important component in SCM is the establishment of appropriate performance measures. A performance measure, or a set of performance measures is used to determine the efficiency and/or effectiveness of an existing system. These measures are categorized as either qualitative or quantative (Beamon, 1998).

2.1.11.1. Qualitative performance measures

Qualitative performance measures are those measures for which there is no single direct numerical measurement, although some aspects of them may be quantified.

1. Customer satisfaction: The degree to which customers are satisfied with the product and/or service received and may apply to internal or external customers.

2. Flexibility: The degree to which the supply chain can respond to random fluctuations in the demand pattern.

3. Information and material flow integration: The extent to which all functions within the supply chain communicate information and transport materials.

4. Effective risk management: It describes the degree to which the effects of these risks are minimized.

5. Supplier Performance: With what consistency suppliers deliver raw materials to production facilities on time and in good condition.

2.1.11.2. Quantative Performance Measures

Quantative performance measures are those measures that may be directly described numerically.

a. Measures based on cost:

1. Cost minimization: Cost is typically minimized for an entire supply chain.

2. Sales maximization: It maximizes the amount of sales dollars or units sold.

3. Profit maximization: It maximizes revenues less costs.

4. Inventory investment minimization: It minimizes the inventory of costs (including product costs and holding costs).

5. Return on investment maximization: It maximizes the ratio of net profit to capital that was employed to produce that profit.

b. Measures based on customer responsiveness

1. Fill rate maximization: It maximizes the fraction of customer orders filled on time.

2. Product lateness minimization: It minimizes the amount of time between the promised product delivery date and the actual product delivery date.

3. Customer's response time minimization: It minimizes the amount of time required from the time an order is placed until the time the order is received by the customer.

4. Lead time minimization: It minimizes the amount of time required from the time a product has begun its manufacture until the time it is completely processed.

5. Function duplication minimization: It minimizes the number of business functions that are provided more than one business entity (Beamon, 1998).

2.1.12. Logistics in Supply Chain Management

"Supply chain and the logistics are critical components of any successful growth strategy." (Richardson et al., 1996) In most cases the effectiveness of logistical functions determines the success of supply chain initiative. "Superior logistical performance is one of the primary opportunity areas where organizations participating in an integrated Supply Chain

Management initiative can make significant improvements." (Handfield and Nichols, 1999). "Logistics professionals will continue to be challenged to manage the movement of products across the supply chain in a timely and cost-effective manner that meets customers' required service levels. In order to meet this challenge, a supply chain-wide logistic strategy is required, which will be the primary driver for the specific logistics strategy within each of the supply chain member organizations. Distribution networks, transportation modes, carrier management, inventory management, warehousing, order processing, and all other related activities will still have to be addressed. The scope of the logistics strategy is now the entire supply chain (not just each individual unit in the chain). It will no longer be necessary or desirable for each supply chain member organization to manage its logistics activities on an independent basis" (Handfield and Nichols, 1999).

The whole process is viewed in terms of two interrelated efforts; material flow and information flow as following:

2.1.12.1. Material Flow

"Establishing integrated supply chains that provide end customers and supply chain member organizations with the materials required, in the proper quantities, in the desired form, with the appropriate documentation, at the desired location, at the right time, and the lowest possible cost lies at the very heart of supply chain management" (Handfield and Nichols, 1999). Logistical operations in the supply chain start with the initial shipment of raw materials from a supplier and are finalized when an assembled product is delivered to a customer. Procurement, manufacturing support, and physical distribution.

1. Procurement

"Depending on the situation, the acquisition process is commonly identified by different names. In manufacturing, the process of acquisition is typically called purchasing. In government circles, acquisition has traditionally been referred to as procurement. In retailing and wholesaling, buying is the most widely used term" (Bowersox and Closs, 1996).

2. Manufacturing Support

Lambert and Stock (1992) describes the importance of manufacturing support as "Without efficient and effective management of inbound materials flow, the manufacturing process cannot produce product at the desired price and at the time they are required for distribution to the firm's customers".

3. Physical distribution

"All physical distribution systems have one common feature: they link manufacturers, wholesalers, and retailer into marketing channels that provide product availability as an integral aspect of the overall marketing process" (Bowersox and Closs, 1996). In physical distribution, the customer is the final destination of a marketing channel. The availability of a product is a vital part of marketing efforts. Unless a proper amount of product is efficiently delivered when and where needed in the supply chain, a great deal of the marketing effort can be jeopardized.

2.1.12.2. Information Flow

"The importance of information to logistical performance has historically not been highlighted. This neglect resulted from the lack of suitable technology to generate desired information. Management also lacked full appreciation and in depth understanding of how fast and accurate communication can improve logistical performance. Both of these historical deficiencies have been eliminated. Current technology is capable of handling the most demanding information requirements. If desired, information can be obtained on a real time basis. Managers are learning how to use such information technology to devise new and unique logistical solutions" (Bowersox and Closs, 1996).

"In the search for a solution to get the right product to the right place at the right time there are essentially five areas that companies should focus on to improve the synchronization of information flow through the supply chain: demand, supply, manufacturing/scheduling, transportation, and network optimization"(Holmes, 1997). Traditionally a major limiting factor in developing good supply chain strategies has been the lack of information flow across organization (Monczka and Morgan, 1998).

1. Planning and Coordination Flows

The coordination is the backbone of any information system architecture among supply chain participants. "Coordination results in plans specifying

1. Strategic objectives,
2. Capacity constraints,
3. Logistical requirements,
4. Inventory deployment,
5. Manufacturing requirements,
6. Procurement requirements,

7. Forecasting" (Bowersox and Closs, 1996).

The aim of establishing a good information planning and coordination flow is to integrate specific activities within a supply chain and to facilitate overall integrated performance.

2. Operational Flows

It is concerned with directing operations to receive, process, and ship inventory as required supporting customers. Operational information requirements deal with

1. Order management,
2. Order processing,
3. Distribution operations,
4. Inventory management,
5. Transportation and shipping,
6. Procurement.

The overall purpose of operational information is to provide the detailed data required for integrated performance of physical distribution, manufacturing support and procurement operations. Whereas planning and coordination flows provide concerning planned activities, operational requirement for information are needed to direct day-to-day operations (Bowersox and Closs, 1996).

2.1.13. Developing and Maintaining Supply Chain Relationships

Every company maintains a variety of different relationships and may not be willing or capable of developing close ties with all parties. Partnerships are resource-intensive investments with not only a financial risk, but maybe more importantly, a strategic risk emerging from the increased vulnerability of the parties and their exposure to opportunistic behavior. Therefore, relationship management is a situational approach and involves the development and maintenance of a portfolio of relationships with different natures, and not only close partnerships (Christopher and Uta Juttner, 2000).

2.1.13.1. The Analysis of Relationship

The relationship management has a great effect on complexity of an integrated supply chain. Relationship management affects all areas of the supply chain and has a dramatic effect of performance. "Supply chain relationships are among the most complex and least understood areas of logistics" (Bowersox and Closs, 1996).

SCM occurs at various levels of relationships, chains and networks. For the studies that exist currently, the levels of analysis do not cross multiple system levels, but rather focus on a single one. The procurement and sourcing strategy is one of the popular issues in the network research level, and the existing works relating to the chain level are mostly based on industrial dynamics and logistics, are focused on speed and cost, efficiency of the orders process, fore- casting and scheduling, and so on.

The relationship level, especially for the bilateral buyer-supplier relationship, is critical to the discussion of organizational partnership and competition. The fact that the relationship is important in shaping SC structure and affecting the way business parties interact has been widely accepted by academics, consultants and operational management. This fact also encourages them to develop methodologies and tools in order to improve or optimize the performance of SC, based on the setting of the existing relationships (Tang et al., 2001).

2.1.13.2. The Buyer-Supplier Relationship

There is some evidence showing that, in recent years, the buyer-supplier relationship has evolved towards a new form in order to respond to intensified competition in industry. These new forms of relationship were defined with the intention of integrating key processes and enhancing quality in the systems of production, manufacturing, stocking and distribution.

Traditionally the buyer-supplier relationships are often characterized by reference to two major types:

1. Adversarial Type

2.Collaborative Type.

The adversarial model, also referred to as the antagonistic model, has characteristics of tough negotiation; focus on price, short-term cont- reacts and multiple sourcing. This is in direct contrast to the collaborative (or cooperative) model. But the current trend of relationships is evolving, towards a more collaborative form based on cooperation, mutual benefit and trust and relational exchange. Under the collaborative model, the buyers' consideration of a preferred supplier is not simply only based on price or cost, but also on the factors that contribute more to the suppliers' competence in production, distribution, and post-purchase service. It is also beneficial for suppliers to be able to get access to the business skill and expertise of their buyer partners. The enormous number of strategies in use today, such as cross-functional team decision-making, supply base rationalization, and long-term contract and relationship can all be categorized as collaborative (Tang et al., 2001).

2.1.13.3. The Buyer Relationship

The buyers typically operated in an antagonistic mode towards their suppliers until the middle of the 1980s. Those buyers attempt to minimize the cost in procuring components or products from their multiple suppliers based on the idea of a short-term contract. Although low cost is substantial, it is not necessarily the delineating factor for buyers. Other types of criteria include high quality in production, delivery, and post purchase service. But until recently, the emerging prevalence of customized production will shorten the life cycle of products, lead to higher costs because of frequent re-equipping of the production line. It means that, in the 1990s, the buyers have been beginning to pay their attention to product variety and quality. This seems that the conventional cost-based strategy is out of date since customized production became more important than standardized production. Taking another viewpoint, when buyers must choose between products with similar levels of price, the decision usually comes down to which product is delivered the fastest or which product is ranked the highest in quality. Buyers will always carefully evaluate the tradeoff between the following two benefits:

1. The rutinization and integration of long-term relationships with suppliers to reduce costs of selection, negotiation, and transaction, execution.
2. The benefit, including potentially better prices, of a spot purchase process aided by the electronic market.

The latter benefit shows that the electronic market provides the means for buyers to purchase at a relatively low price, and the former benefit demonstrates the cost reduction received from mutual trust and commitment, which exists in well established, long-term relationships. It is apparent that the features buyers desire in a product usually falls into two categories: cost (or price) and quality. The cost category involves the cost of searching, identifying, evaluating, and selecting a specific trading supplier as well as the cost of executing a transaction including the physical payment for products. The quality category includes the quality of the product itself, quality of ordering, quality of delivery, quality of post-purchase service, and so forth. The buyer always expects that the suppliers are competent in total quality management, including simplifying production, synchronization of the order cycling and production scheduling, and personal service to their customers. Other factors which influence the way buyers choose their suppliers include the responsiveness of a supplier, the staying power and growing potential of a supplier, a long track record, and whether they will lose the ability to acquire or to fully use complementary products in the future.

It can also be said that, from another point of view, the buyer is always seeking suppliers who can provide the highest level of customer service. The level of customer service often positively correlates with market response, such as market share, customer preference and satisfaction, total sale or profit (Tang et al., 2001).

2.1.13.4. The Supplier Relationship

The intensified competition in the marketplace has forced companies to change the ways They manage businesses. The new features exhibited by many markets include the increased quality and reliability in products, more choice in existing products ranges or new products, more customization, faster satisfaction of customer need, freedom to change late in the order cycle, increasing level of customer service, etc. These features, which represent the requirements of the market that suppliers have to fulfill, can be extrapolated to facilitate the suppliers' obligation to set objectives. On the other hand, the performance targets and benchmarks of SCM, which comprise cycle time, quality, cost and customer satisfaction, can be linked with a one's best practices to determine the potential ability to compete in a chosen market. In addition, they can be used to help evaluate, position, and implement supply chain applications performance. The evolution of the distribution process from functionally oriented departments to supply-chain integrators can help suppliers strive for multiple operational advantages such as minimum inventory level, fast cycle time from source to shelf, and direct processing of products or materials. In addition to designing and operating physical networks of distribution partners, the supplier has to design and operate a global information network of data collection, communication, and processing in order to satisfy the requirements of distribution or logistics processes. These processes include tailored services, maximum profit and minimum cost objectives when meeting service targets, complete control and accountability, channel linkage, and so on.

The consensus of most literatures on this area of measuring the performance is matched by a consensus on the goals or objectives set by suppliers, and it is usually used as a trigger for suppliers to develop planning systems with the capability of collecting, analyzing, and storing information to reduce cost, improve response time and user control, and provide various backup mechanisms. The elements of SC planning systems should include forecasting, inventory planning, and distribution requirements planning, and each of these elements has its own set of objectives, which lead to improving the functionality of SC planning. Such systems, which are usually built upon the IT of today, are facilitators for information sharing among participants in SC. This is especially important when suppliers integrate their resources as a response to rival companies or to satisfy customer needs. The advantages brought to suppliers by information sharing usually involve direct and frequent communication with customers, elimination of problems and concerns, clarification of need and expectation, and various other advantages. Such advantages are usually useful and beneficial for suppliers as they rethink or reconstruct the relationship with their customers to establish and sustain a successful customer/supplier partnership (Tang et al., 2001).

2.1.14. Information Technologies in Supply Chain Management

By 1980, the information revolution was in full swing in the world's advanced economies. During this period, many standard business processes and functions such as customer order processing, inventory management, and purchasing were altered through the use of computer technology. However, only as the variety of available information technologies and capabilities began to grow exponentially mid-decade, did a more expanded information technology (IT) paradigm begin to emerge (Handfield and Nichols, 1999).

Recent development in technology have brought information to the forefront of resources from which forward-thinking firms can cultivate genuine competitive advantage. These technologies provide the means for multiple organizations to coordinate their activities in an effort to truly manage a supply chain. As the rate of these technological advances increases, the cost associated with this information has decreased. Simultaneously, the speed with which this vital information can be made useful and applicable in a variety of business situations continues to increase (Handfield and Nichols, 1999).

Supply chain management is concerned with the flow of products and information between the supply chain member organizations. At the limit, it encompasses all of those organizations (i.e., suppliers, customers, producers, and service providers) that link together to acquire, purchase, convert/manufacture, assemble, and distribute goods and services, from suppliers to the ultimate end users (Handfield and Nichols, 1999). These flows are bidirectional. (Harrington, 1995).

The development of supply chains over the years has been slow. Companies developed individual parts of their supply chains beginning first with the transportation component and moving on to include warehousing, finished goods inventory, materials handling, packaging, customer service, purchasing, and finally, raw materials inventory. The goals of supply chain systems are multi-dimensional and include cost minimization, increased levels of service, improved communication among supply chain companies, and increased flexibility in terms of delivery and response time (Lancioni et al., 2000).

Throughout the 1960s, 1970s, and 1980s the ability of firms to achieve these goals was limited, since the communication and knowledge links in the existing supply chains did not bring together all of the key databases. Also, there was the reluctance on the part of firms in the supply chain to share data with each other. This hesitancy was due to a variety of factors, including the perceived threat of giving away competitive advantage to other firms, the sharing of sensitive information such as inventory levels and production schedules with other channel members, and the potential of loosing customers to other competitors (Lancioni et al., 2000).

Electronic data interchange (EDI) had the same effect on the fears of the data sharing in the supply chain. Here, firms were actually linking up their companies with computer-to-computer ordering and data exchange. The fear was greatest among small companies. Implementation of EDI required an investment in computers and software, on the parts of both the vendor and the buyer. Standardization was also a requirement that made the switch to EDI a lot slower than with JIT (Lancioni et al., 2000).

2.1.14.1. Information Systems and Supply Chain Management

With the emergence of the personal computer, optical fiber networks, the explosion of the Internet and the World Wide Web, the cost and availability of information resources allows easy linkages and eliminates information-related time delays in any supply chain network. These means, that organizations are moving toward a concept known as Electronic Commerce, where transactions are completed via a variety of electronic media, including electronic data interchange, electronic funds transfer (EFT), bar codes, fax, automated voice mail, CD-ROM catalogs, and a variety of others. With these improvements old "paper" type transactions are becoming increasingly obsolete. All required information is recorded electronically, and associated transactions are performed with a minimum amount of human intervention. Recent developments in database structures allow part numbers to be accumulated, coded, and stored in databases, and electronically ordered. This means that with the application of the appropriate information systems, the need to constantly monitor inventory levels, place orders, and expedite orders will soon become a thing of the past (Handfield and Nichols, 1999).

The proliferation of new telecommunications and computer technology has also made real-time, on-line communications throughout the entire supply chain a reality. These systems are now being linked between suppliers, manufacturers, distributors, retail outlets, and ultimately, customers, regardless of location. These technologies are supply chain "enablers", in that they can substantially reduce paperwork, improve communication, and reduce lead-time and non-value-added activities if properly implemented (Hand field and Nichols, 1999).

Managers developing information systems should not visualize information as a set of repetitive transactions between entities such as buyers and suppliers, or distributors and retailers. Rather, an ideal system should span all functions and organizations throughout the entire supply chain (Handfield and Nichols, 1999).

2.1.14.2. The Implementation of Information Systems in Supply Chain Management

The process of implementing an integrated supply chain has been shown to be very difficult. In many cases, problems occur in the implementation of information systems, such that the appropriate information is not available to the people who need it. In other cases, the information is available, but supply chain members are reluctant to share it, due to a lack of trust and a fear that the information will be revealed to competitors (Handfield and Nichols, 1999).

2.1.14.3. The Importance of Information in an Integrated Supply Chain Management

Prior to the 1980s, a significant portion of the information plows between functional areas within an organization, and between supply chain member organizations, were paper-based. In many instances, these paper-based transactions and communications were slow, unreliable, and error prone. Conducting business in this manner was costly because it decreased firms' effectiveness in being able to design, develop, procure, manufacture, and distribute their products. This approach also impeded efforts to develop and capitalize on successful interorganizational ventures. During this period, information was often overlooked as a critical competitive resource because its value to supply chain members was not clearly understood. However, firms that are embarking upon supply chain management initiatives now recognize the vital importance of information and the technologies that make this information available (Handfield and Nichols, 1999).

IT infrastructures today may be quite complex and comprehensive, supporting the firm's communication networks, databases, and operating systems. In fact, "IT infrastructure capabilities underpin the competitive positioning of business initiatives such as cycle time reduction, implementing redesigned cross-functional processes, utilizing cross-selling opportunities and capturing the channel to the customer"(Broadbent and Weill, 1997). These infrastructures also support the development, management, and maintenance of interorganizational supply chains (Handfield and Nichols, 1999).

In a sense, the information systems and the technologies utilized in these systems represent one of the fundamental elements that "link" the organizations of a supply chain into a unified and coordinated system. In the current competitive climate, little doubt remains about the importance of information and information technology to the ultimate success, and perhaps even the survival, of any supply chain management initiative (Handfield and Nichols, 1999).

Several well-known firms involved in supply chain-type relationships owe much of their success to the notion of information and the systems utilized to share this information with one another. Among the most notable examples are Procter & Gamble (P&G) and Wal-Mart. through a series of agreements with giant retail customers. P&G has made a major commitment to the development of dedicated customer teams to handle these major accounts. A primary objective of these teams is to facilitate the sharing of information between the firms and will typically address a full range of logistics, finance, accounting, MIS, and supply issues (Handfield and Nichols, 1999).

According to Bowersox and Closs (1996), timely ad accurate information is more critical now than at any time in the history of American business. Three factors have strongly impacted this change in the importance of information. First, satisfying, in fact pleasing, customers have become something of a corporate obsession. Serving the customer in the best, most efficient, and effective manner has become critical, and information about issues such as order status, product availability, delivery schedules, and has become a necessary part of the total customer service experience. Second, information is a crucial factor in the managers' abilities to reduce inventory and human resources requirements to a competitive level. Finally, information flows play an essential role in the strategic planning for and deployment of resources (Handfield and Nichols, 1999).

Shared information is widely recognized as one of the most important enablers for supply chain integration. Even within a well-organized supply chain, disruptions and inefficiencies can result from inadequate information sharing. Both information technology and integrated information systems play significant roles in coordination of the supply chain. Integrated information systems are needed to coordinate the movement of information throughout the supply chain (Franciose, 1995).

A key notion in the essential nature of information systems in the development and maintenance of successful supply chains is the need for virtually seamless bonds within and between organizations. This means creating intraorganizational processes and links to facilitate delivery of seamless information between marketing, sales, purchasing, finance, manufacturing, distribution and transportation internally, as well as interorganizationally, to customers, suppliers, carriers, and retailers across the supply chain. Perhaps more importantly, it means alteration of perspective, at the firm's highest levels. Changes in thinking that become necessary include aligning corporate strategies to the IT paradigm, providing incentives for functions to achieve common goals through the sharing of information, and implementing the the technologies to redesign the movement of goods to maximize channel value and lower cost (Handfield and Nichols, 1999).

2.1.14.4. Information and Technology Applications for Supply Chain Management

Several technologies have gained popularity recently, due to their ability to facilitate the flow of information across the supply chain. Many of the technologies fall, in today's language, under the heading of electronic communication. Other relevant technologies include bar coding/scanning, data warehouses and decision support systems. It is interesting to note that several of these technologies have been available for a number of years: however, the application to interorganizational supply chains is a relatively recent phenomenon (Handfield and Nichols, 1999).

1. Electronic Commerce

Electronic commerce is the term used to describe the wide range of tools and techniques utilized to conduct business in a paperless environment. Electronic commerce therefore includes electronic data interchange (EDI), e-mail, electronic funds transfers, electronic publishing, image processing, electronic bulletin boards, shared databases, and magnetic/optical data capture (such as bar coding), the Internet, and Web sites. ("The IT Committee's Top 10 List, 1997) Electronic commerce is having a significant effect on how organizations conduct business. Companies are able to automate the process of moving documents electronically between suppliers and customers in such a manner that the entire process is handled electronically; no paperwork is involved. With the rise of the Internet and the ability to transfer information cheaply and effectively over the whole world, electronic commerce is becoming a major focus for many organizatiions and represents a significant opportunity for integrated supply chain management efforts (Handfield and Nichols, 1999).

2. Electronic Data Interchange

EDI facilitates rapid transmission of large amounts of information with far greater accuracy. Like bar codes, EDI involves both technological developments and standardization of methods for data transfer. At this point, standards have been developed for business-to-business communications, including purchase orders, shipping invoices, and funds transfer. And by eliminating the clerical and mailing activity associated with paper-based information, EDI reduces costs, time delays, and errors (Abernathy et al., 2000).

EDI refers to a computer-to-computer exchange of business documents in a standard format. EDI describes both the capability and practice of communicating information between two organizations electronically instead of the traditional forms of mail, courier, or fax. Capability refers to the ability of the various members of the supply chain to use their computer systems to communicate effectively, whereas the practice refers to the ability of the members of the supply chain to willingly share and effectively utilize the information exchanged. The benefits of EDI are numerous, including:

1. Quick access to information,
2. Metter customer service,
3. Reduced paperwork,
4. Better communications,
5. Increased productivity,
6. Improved tracing and expediting,
7. Cost efficiency,

8. Competitive advantage, and

9. Improved billing (Handfield and Nichols, 1999).

EDI improves productivity through faster information transmission as well as reduced information entry redundancy. Accuracy is improved by reducing the number of times an individual is involved in data entry. The use of EDI results in reduced costs on several levels, including: reduced labor and material cost associated with printing, mailing, and handling paper-based transactions; reduced telephone and fax transmissions; and reduced clerical costs (Handfield and Nichols, 1999).

EDI is also tremendously beneficial in counteracting the bullwhip effect described earlier. Through the use of EDI, supply chain partners can overcome the distortions and exaggerations in supply and demand information by using technology to facilitate real-time sharing of actual demand and supply information (Handfield and Nichols, 1999).

The use of EDI technologies has numerous applications throughout the supply chain. For example, several consumer products manufacturers such as Campbell's Soup, Nabisco, and Quaker Oats have implemented EDI to support their continuous replenishment program (CRP) with many of their customers. In these programs, it is also referred to as vendor-managed inventory (VMI) systems, the downstream members of the supply chain, in this case the retailers, become essentially passive in the information-sharing process. Through the CRP, the manufacturers gain access to demand and inventory information for each downstream supply chain site and make necessary modifications and forecasts for them. Estimates indicate that implementation of these types of applications have resulted in inventory reductions of up to 25 percent (Handfield and Nichols, 1999).

EDI Electronic Data Interchange refers to an application of information technology that allows trading partners to send, receive, and process electronic documents from computer to computer. EDI systems contribute to reducing paperwork as well as lowering administrative costs and enhancing competitive advantage. It is important to understand a few critical aspects of EDI in order to obtain significant benefits from the implementation of the system (Lee and Han, 2000).

3. Bar Coding and Scanning

At its most basic level, bar coding refers to the placement of computer readable codes on items, cartons, containers, and even railcars. This particular technology application drastically influenced the flows of product and information within the supply chain. Bar coding and electronic scanning are identification technologies that facilitate information collection and exchange, allowing supply chain members to track and communicate movement details quickly with a greatly reduced probability of error (Handfield and Nichols, 1999).

Inventory management can be made more accurate with the use of bar code readers that can transmit stock levels to computers. The data can be accessed by the Internet and transmitted directly to logistics managers responsible for the inventory. This system is quicker and more accurate, since stock levels can be reviewed frequently (Lancioni, 2000).

4. Data Warehouse

Although definitions vary, a data warehouse is generally thought of as a decision support tool for collecting information from multiple sources and making that information available to end users in a consolidated, consistent manner. Rather than trying to develop one unified system or linking all systems in terms of processing, a data warehouse provides a means to combine the data in one place and make it available to all of the systems (Handfield and Nichols, 1999).

5. Internet

The Internet has emerged in the recent past as a dynamic medium for channeling transactions between customers and firms in a virtual marketplace. In particular, the World Wide has emerged as a powerful new channel for distribution, rendering many intermediaries obsolete, and radically revamping the value chain in several industries. The Internet is challenging the traditional distribution structures that firms have employed to get goods and services to market. In addition, it is forcing firms to reevaluate their value proposition to customers, and meet the challenges of more nimble rivals (Rao, 1999).

In terms of advancement in technology and communications capabilities, perhaps the most influential development over the past decade has been both adaptation of the Internet from strictly government and research applications into the areas of commerce and mass communications. At the most basic level, a network of networks, the Internet provides instant and global access to an amazing number of organizations, individuals, and information sources. Through systems like the popular World Wide Web (the Web), Internet users are able to conduct organized searches on specific topics as well as browse various Web sites to discover the vast resources available to them through their computer (Handfield and Nichols, 1999).

6. Intranet/Extranet

Intranet is networks internal to an organization that use the same technology that is the foundation of the global Internet. By using Web browsers and server software with their own internal systems, organizations can improve internal information systems and link otherwise incompatible groups of computers. Internal networks often start out as to link employees to company information, such as lists, product prices, or benefits. Because internal networks use the same language and seamlessly connect to the Public Internet. They can easily be extended to include customers and suppliers, forming a supply chain "Extranet" at far less cost than a proprietary network (Handfield and Nichols, 1999).

7. World Wide Web

The World Wide Web is the Internet system for hypertext linking of multimedia documents, allowing users to move from one Internet site to another and to inspect the information available without having to use complicated commands and protocols (Handfield and Nichols, 1999).

The implications of the Web for business applications are obvious and far-reaching. Web-based technology and tools have been developed in virtually every industry and form of commerce supply chain organizations are no exception (Handfield and Nichols, 1999).

8. Decision Support systems

The basic objective of a DSS is to provide computerized support to complex no routine and partially structured decisions. DSS will help decision makers identify opportunities for improvements across the supply chain, far beyond what even the most experienced manager could provide through intuitive insight. DSS will allow management to look at the relationships across the supply chain, including suppliers, manufacturing plants, distribution centers, transportation options, product demand, relationships among product families, and a host of other factors to optimize supply chain performance at a strategic level.

Specific technologies that may be utilized for an effective Supply Chain Management DSS Include the following:

1. SQL interface
2. Expert system rules
3. Scheduling algorithms
4. Linear programming capabilities

2. Inventory Management and the Internet

The Internet has affected inventory management most dramatically in the ability of firms to be proactive in the management of inventory systems. This is demonstrated in the ability of firms to notify customers of order-shipping delays and inventory emergencies. The research showed that the information available to inventory managers is becoming more readily available because of the reporting systems that can be used through the Internet. This includes finished-goods inventory levels at manufacturing and field level depots along with raw material levels at central and regional assembly locations. The Internet also provides managers with the ability to track out-of-stock inventory items in field depots. The overall benefit of the Internet to firms in managing inventory in their supply chains is to keep inventory levels low, reduce overall holding costs, and still provide high levels of customer service (Lancioni et al., 2000).

3. Transportation and the Internet

Transportation typically is the second highest cost component in a supply chain, accounting for approximately 25% of the overall operating costs. The monitoring of pickups at regional distribution centers by carriers is the most popular application of the Internet in this area. This is particularly important for a company, since tracking shipments to regional depots provides the firm with data on the reliability performance of the carriers it is using. This enables transportation managers to make sure that the motor carriers they use are meeting their promised arrival times. It also provides managers with the information they need to inform carriers of shipment delays as they occur, and to not have to wait for days before the information becomes available for corrective measures to be taken (Lancioni et al., 2000).

4. Order Processing and the Internet

Over half of the firms use the Internet for this purpose. This has dramatically reduced the costs of order processing, which before the Internet accounted for approximately 18% to 20% of the total cost of managing a supply chain system. A major component of this cost saving is the reduction of paperwork involved in traditional order processing systems because of the Internet. Another large advantage of the Internet in order processing is the speed at which orders can be processed. The reduction in order-cycle time, or the time between the orders is placed and the time it is received by a customer, has been reduced by as much as one-half (Lancioni et al., 2000).

5. Blocked scheduling
6. Multisite/multistage scheduling
7. Graphical user interface
8. User definable database
9. Available-to-promise
10. Demand management (Handfield and Nichols, 1999).

2.1.15 The Role of Internet in Supply Chain Management

The Internet has grown rapidly over the last 5 years. It is predicted that more than 100 million households will be connected to the World Wide Web by 2002. But what about the use of the Internet in business-to-business supply chain applications? Here, the greatest potential of the Internet is being realized by speeding up communication between customers and their suppliers, improving service levels, and reducing logistics costs. Internet is being used in managing the major components of supply chains including transportation, purchasing, inventory management, customer service, production scheduling, warehousing, and vendor relations (Lancioni et al., 2000).

Lancioni et al. (2000) listed the seven substantive supply chain decision areas that were affected by the use of Internet. These are as follows:

1. Purchasing/procurement
2. Inventory management
3. Transportation
4. Order processing
5. Customer service
6. Production scheduling
7. Relations with vendors

1. Purchasing and the Internet

The purchasing function in U.S. firms has been streamlined through the use of the Internet. General Electric, for example, has reduced its purchasing staff by more than 50 percent and permits on-line purchasing from vendor catalogs by each department. The paper-work flows have been reduced, and order-cycle times -the time from when the order is purchased to the time it is delivered to the company—has decreased by 40 percent (Lancioni et al., 2000).

5. Customer Service and the Internet

The Internet gives customers 24-hour access to a company's service department, enabling customers to immediately notify companies of any service issues or problems that may arise. The overall effect has led to reduced response times and resolutions of customer service problems. The Internet has improved the two-way flow of communication between firms and their customers. This is demonstrated by the results of the research that show that U.S. companies are using the Internet not only for service issues, but for selling their products and services as well (47.9%). This two-way communication capability can have a profound effect on cementing customer-firm relationships. Experience with Internet service systems shows that customers whose service issues are dealt with quickly and to their satisfaction, are more likely to want to purchase the firm's products again. The Internet can build strong product and service loyalty if used appropriately in the customer service area (Lancioni et al., 2000).

6. The Internet and Vendor Relationships

An important factor in vendor relations is the ability of a company to rate the performance of its vendors based on the elements agreed to in their negotiated contracts. These performances include such factors as deliveries to company warehouses and depots, the on-time performance of the carriers used by the vendors, and vendor raw material inventory and general stock levels. The benefits of these evaluating systems improve the overall quality of vendor performance; lower purchasing costs, and improves the productivity of vendor operations. This information enables companies to form strategic vendor alliances based on solid informational bases developed from Internet monitoring systems (Lancioni et al., 2000).

7. The Internet and Production Scheduling

Production scheduling has traditionally been the most difficult aspect of SCM. The reasons are:

1. The high level of inaccuracy of sales forecasts,
2. The lack of raw material information from vendors;
3. The general paucity of information regarding fluctuations in vendor-stock levels and customer demand.

The Internet has enabled U.S. firms to minimize the difficulty in their production scheduling by improving the communication between vendors, firms, and customers. This has resulted in more accurate sales forecasting, which in turn has greatly improved production scheduling (Lancioni et al., 2000).

8. The Challenge of the Internet

The growth of the Internet has presented supply chains with many significant opportunities for cost reduction and service improvements. These opportunities include (Lancioni et al., 2000):

1. On-line vendor catalogs from which buyers can find, select, and order items directly from suppliers without any human contact.
2. The ability to track shipments using a wide variety of modes including truck, rail, and air transport.
3. The ability to contact vendors or buyers regarding customer service problems from late deliveries, stock-outs, alterations in scheduled shipment dates, late arrivals, and a wide variety of other service issues.
4. The ability to reserve space in public warehouses for anticipated deliveries to market locations.
5. The ability to schedule outbound shipments from private and public distribution centers on a 24-hour basis.
6. The ability to provide 7-day/24-hour worldwide customer service.
7. The ability to receive orders from international customers.
8. The ability to check the status of orders placed with vendors.
9. The ability to place bids on projects issued by government and industry buyers.
10. The ability to notify vendors of changes in configurations in products that are produced to order.
11. The ability to pay invoices electronically and to check outstanding debit balances.
12. The ability to track equipment locations including rail cars, trucks, and material handling equipment
13. The ability to directly communicate with vendors, customers, etc. regarding supply issues on a 7-day/24-hour basis via e -mail
14. The ability to schedule pickups and deliveries
15. The ability to be more responsive to customer service problems
16. The ability to reduce service costs and response time.

2.1.16. Benefits Of Supply Chain Management

The integrated management of information and materials across the supply chain offers the benefits of increasing the value-added by supply chain members, reducing waste, reducing cost, and improving customer satisfaction. However deploying and managing this strategy is a challenging and significant task (Handfield and Nichols, 1999).

Change has become a constant state of existence and it is accelerating. To keep up with nimble global competitors and to react effectively to global market inputs, companies have accelerated the product development lifecycle from years down to months. With only a limited time frame to react, accurate forecasting and flawless execution have become critically important. Supply chain integration requires a re-examination of these industrial revolution assumptions, and a move beyond functional excellence.

2.1.17. Conclusion

SCM is directing our thinking toward opportunities that exist, by managing across functional and company boundaries. Although SCM is a new term to describe the man-agreement of product-flow activities, the concept has been imbedded in physical distribution and logistics since the beginning of the 1960s. What is new is the emphasis given to boundary-spanning management. Exploring the opportunities that SCM provides is a popular research area. The elements of SCM are captured in a trilogy of in-trafunctional, interfunctional, and interorganizational coordination. Much effort over the years has been directed toward managing the product-flow activities in-trafunctionally, probably because they were under the immediate control of the product-flow manager and easiest to accomplish. Coordination beyond the immediate function is difficult but offers promise of yet under explored opportunities. Identifying boundary-spanning opportunities is reasonably easy, at least in a theoretical sense. Armed with data and basic management models, the benefits of managing interfunctionally or interorganizationally can be demonstrated. The difficulty remains in achieving the projected benefits. Since cooperation is usually among members that either have different reward systems or are legally separate, members need to realize benefits from their cooperation. The most challenging situation occurs when the benefits "pool" with some members at the detriment of others. Balancing these benefits so that all members are better off for their cooperation is the new challenge for supply chain managers. This new challenge will require that managers find a way to measure and report costs and other data, such as demand and customer service that span company boundaries; share information about the level of the benefits and with which members they reside; and reallocate the benefits that put some channel members in a worse position as a result of their cooperation. Success in managing in this new arena will be the next frontier for lowering costs and increasing service in the product-flow channel (Ballou et al., 2000).

2.2. GROUP DECISION SUPPORT SYSTEMS (GDSS)

GDSS has effects on group process efficiency and group outcome quality have often been associated with an increase in the quantity of ideas generated by the group and a reduction in group discussion time in hours. Regarding group outcome quality, main factors were an increase in the quality of individual contributions, rather than in the number of contributions as in GDSS-supported groups. That is, in electronically communicated (EC)-supported groups, the number of individual contributions seems to be largely reduced, whereas the length of individual contributions seems to be considerably increased, in comparison with face-to-face (Kock, 2001).

2.2.1. Group Decision Making

Decision-making is certainly a very crucial component of human activities. A decision process involves the whole range of activities concerning the decision-making. One single individual cannot do selecting the best course of action. Therefore Group Decision Making (GDM) is widespread in most organizations. Group decision process is different from the individual decision process because of characteristics and tasks. In GDM more than one decision units perform simultaneously. Information transmits among these decision units. The stages of group decision process are:

1. Problem identification
2. Sharing information
3. Alternative generation
4. Alternative evaluation
5. Consensus reaching.

In-group situations, multiple individual interpretations of the best solution must be aggregated into the best single group interpretation. The group interpretation of the best course action however must reflect a consensus of individual opinions. Many important decisions are based on the preferences of group of people. Therefore aggregation of the participants' preferences must be done (Lei and Youmin, 1996).

Groups often face complex decisions; decisions in which the decision alternatives are not clearly defined and the criteria for choosing an alternative are subject to dispute within the group (Easley and Mackay, 1995).

According to Ngwenyama and Bryson (1999) Group Decision Making have four common limitations. These are as following:

1. The inability to deal with vagueness of human decision makers in articulating preferences;
2. Difficulties in mapping qualitative evaluation to numeric estimates;
3. Problems in aggregating individual preferences into meaningful group preference;
4. The lack of simple user friendly techniques for dealing with a large number of decision alternatives.

2.2.2. Decision Support Systems (DSS)

Decision support systems are computer-based systems that bring together information from a variety of sources, assist in the organization and analysis of information, and facilitate the evaluation of assumptions underlying the use of specific models. In other words, these systems allow decision makers to access relevant data across the organization, as they need it to make choices. The DSS allow decision makers to analyze data generated from transaction processing systems and other internal information sources easily. In addition DSS allow access to information from outside the organization. Finally, DSS allow decision makers the ability to analyze the information in a manner that will be helpful that particular decision and will provide that support interactively (Sauter, 1997).

2.2.3. Group Support Systems (GSS)

Group Support Systems can be defined as computer based systems used to support intellectual collaborative work. It is a generic term that covers a line of group-oriented support systems including Group Decision Support Systems (GDSS), Electronic Meeting Systems (EMS), and Computer Mediated Communication Systems (CMCS) and groupware. Though having different names and using different technologies, the central goal of these systems is to make use of information technology to facilitate organizational communication, coordination, and cooperation and to support group decision making (Gillenwater, et.al. 1995).

Group Support Systems provide tools and techniques to assist in facilitating and managing group discussions, issue exploration, problem definition, and analysis, consensus seeking, group writing, activity coordination, knowledge sharing and accumulation, and data, and decision analysis (Ngwenyama et al., 1996).

2.2.3.1.Modes of Group Support Systems (GSS)

Generally there are two major environmental dimensions in a GSS setting: Group proximity and time dispersion. As illustrated in Figure 2.4 a GSS, can be developed to support group activities concurrently (same time) or non-concurrently (different times), in a decision room (same place), or in geographically dispersed locations (different places). Recently the research and development of GSS to support activities of geographically distributed groups in any location at any time has generated much attention. CMCS provides non-concurrent group communication through such applications such as electronic mail, computerized conferencing facilities, and bulletin boards. Likewise GDSS integrates communications, computers and decision aids to facilitate concurrent group decision-making processes (Gillenwater et.al. 1995).

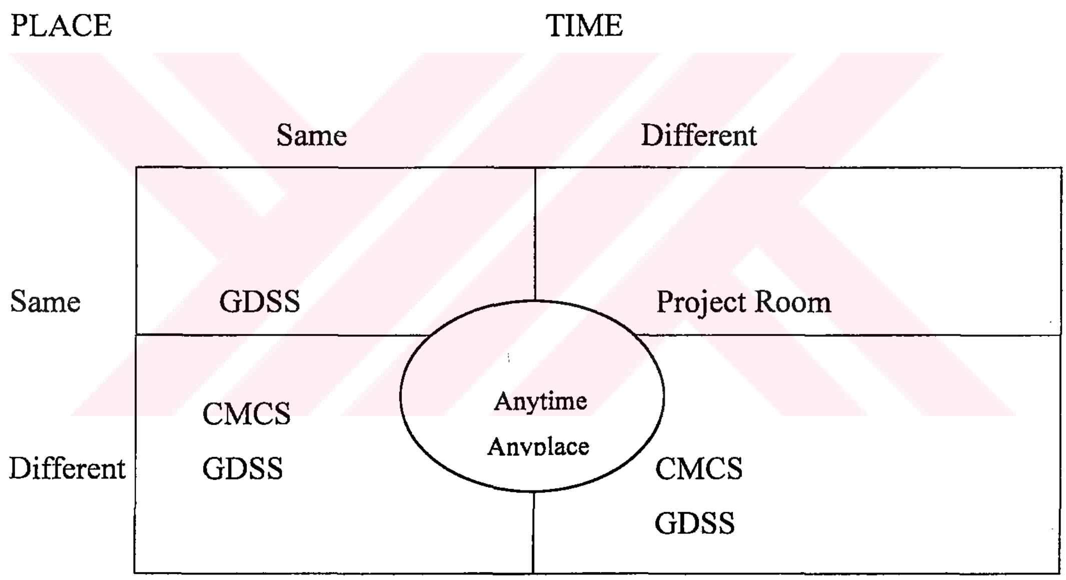

Figure2.4: Modes of the Group support Systems (Gillenwater et.al. 1995).

2.2.4. Group Interaction

The computer support to group interaction consists of three basic functionalities:

1.Information sharing,

2.Coordination,

3.Multiuser-interface.

Information sharing allows establishing a common context between individuals, a functionality that requires the specification of a data consistency model. Data consistency can be preserved through concurrency control mechanisms, e.g. locking, versioning, history, views, etc. Group interaction adds the notion of interdependence and coordination to information sharing. Interdependence means that is, in cooperative settings, activities flow from one individual to another, while coordination introduces the requirement of managing the dependencies between activities. Several coordination mechanisms have been proposed e.g. free mechanisms, that rely on the social protocols established by users and do not control the access to the medium, floor-control, semiformal, based on language and formal mechanisms. The multi-user-interface is responsible for mediating users and the system. The interface-interface must define a public space, shared by all users, and maintain visual consistency of objects, which are placed in the public space (Antunes, 2001).

It must also manage the interconnection of private and public spaces, since group activities are assembled from a mixture of private and public activities. One more interface-interface requirement exists: It must provide users awareness on cooperative activities. The computer support to group interaction can also be characterized in time/space domains. The combination of these domains defines four different types of systems:

1. Same-time/same-place, which focus on the computer support to information sharing, since coordination and interface-interface can be established face-to-face;

2. Different-time/different-place, which minimizes interface-interface mechanisms, fundamentally because most work is done in the users' private spaces,

3. Different-time/same-place, where few cooperative systems can be placed, minimizes information sharing and coordination, emphasizing single-user interface aspects of interactions,

4. Same-time/different-place, which requires the full spectrum of group interaction support.

In same-time/different-place systems, information sharing is necessary to preserve a shared context between users that are not face-to-face. Coordination is essential to manage Interventions by users that are simultaneously using the system; and interface-interface is essential to preserve the degree of co-presence of cooperative work (Antunes, 2001).

2.2.5. Group Decision Support Systems (GDSS)

Organizations today use many experts to support decision-making. Decision makers at every level of a firm are compelled at times to turn to one or several experts in order to make a single decision. This dependence on experts is likely to continue as the industrial and commercial world keep specializing while professionals and experts increase their level of expertise in smaller and smaller areas. Virtually any field has its experts, who may work as individuals or in groups and Group Decision Support Systems are gaining recognition as tools to aid decision makers (Beeri and Spiegler, 1996).

The increasing complexity of the socio-economic environment makes it increasingly difficult for a single decision maker (DM) to consider all relevant aspects of a problem. As a result, many organizations employ groups in decision making. This trend also has important consequences for research on decision support, in which a group decision support system (GDSS) intended to aid multiple cooperating decision makers has become an important topic.

There is an increasing trend for the necessity of an interactive procedure because a selection is not generally made in a single step, and the quality of decision results is enhanced through learning effects during all steps of the interactive decision support (Kim et al., 1998).

Group Decision Support Systems (GDSSs) and other electronic meeting technologies are helping many organizations make better, quicker decisions by providing support for the anonymous and simultaneous exchange of ideas and preferences. Numerous studies have shown that group members using the systems participate more, generate more comments, and are more satisfied than when using traditional meeting techniques (Aiken and Vanjani, 1997).

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Expertise in smaller and smaller areas. Virtually any field has its experts, who may work as individuals or in groups, and GDSS are gaining recognition as tools to aid decision making (Beeri and Spiegler, 1996).

2.2.5.1. The Definition of the GDSS

Lewis and Steier (1994) defined GDSS as a system of networked computers and specialized software that allows a group of practitioners to interact simultaneously, anonymously, and in full awareness of the responses of others in the group.

Blanning and Reinig (2001) defined GDSS as a technology known as Electronic Meeting Systems (EMS) that allows people to discuss matters anonymously among themselves. Each person (called a participant) is seated in front of a personal computer, and the computers are connected by means of a local area network. The participants can make comments, view the comments of others, and respond to these comments, all without revealing their identities.

Pendergast and Hayne (1999) defined GDSS as an interactive computer-based system that facilitates the solution of unstructured problems by a set of decision-makers working together as a group.

Matsatsinis and Samaras (2001) defined GDSS as a set of software, hardware, language components and procedures that support a group of people engaged in a decision related meeting and its major function is to support the three common group activities information retrieval, sharing, and use.

According to Beruvides (1995), GDSS is simply an array of computers with specific software packages to allow groups of individuals to meet (interact) from separate locations in a simultaneous manner.

GDSS are computer systems arranged within a local area network that use a combination of decision support technologies and computer communication to enhance group problem solving (Daily and Steiner, 1998).

A GDSS is an interactive computer-based system that facilitates the solution of ill-struc tured problems by a set of decision makers which work together as a team (Karacapilidis and Pappis, 1997).

GDSS is only likely to be economically viable when used to support ill-structured, complex, and probably strategic decision-making. By their very nature GDSSs are, and will be, a complex system of computer hardware, computer, software, procedures, environments, and facilitation in a mix of proportions (Eden, 1995).

GDSS is most closely associated with brainstorming meetings where all the participants are interacting through a networked computer supported system so that the meeting can occur in parallel (Eberts and Habibi, 1995).

GDSS have been defined as interactive computer integrated systems that bring together decision science techniques with computer communication to promote group interaction structure and enhance solutions to group problems (Daily et al., 1996).

A GDSS combines communication, computing, and decision support technologies to facilitate formulation and solution of unstructured problems by a group of people (Rao and Turoff, 2000).

Group Decision Support Systems (GDSS) are defined as a useful methodology for enhancing effectiveness and satisfaction in computer-supported work groups. GDSS are interactive computer-based systems for generating solutions to unstructured problems. GDSS provide features, such as anonymity and electronic brainstorming (EBS), to address decision-making and communication problems associated with traditional face-to-face group interaction (e.g., evaluation, apprehension, production, and blocking (Sosik et al., 1998).

GDSS is only likely to be economically viable when used to support ill structured, complex, and probably strategic decision-making. By their very nature, GDSS s are and will be, a complex system of computer hardware, computer software, procedures, environments, and facilitation in a mix of proportions (Eden, 1995).

GDSS are computer-based systems that facilitate group interaction, and decision-making through individual idea generation and structured group idea evaluation (Daily et al., 1996).

The mainstream GDSS movement is not much interested in the technical mechanics of collective decision-making, per se. Its emphasis is on the precursors to collective decisions, on the development of facilities to support the solicitation, sharing and organization of the inputs to fuel algorithmic decision aids (Sutherland, 2000).

2.2.5.2.The Purpose of GDSS

The purpose of GDSS is to integrate the separate decision processes of the members of a group of managers or analysts, such as a committee, the members of a department, or an ad hoc team. Each participant (i.e., member of the group) is seated in front of a desktop (client) computer connected to a server. The participants can enter comments, view the comments of others, and respond to them if they wish. The process is both anonymous and simultaneous. When a participant enters a comment, the comment is numbered by the GDSS software, but the participant is not identified. Thus, the participants respond to numbered comments, not to named individuals. This allows the participants to engage in frank and open discussion about controversial subjects and to focus on ideas rather than on personalities. In addition, participants enter their comments simultaneously, which is far more efficient for larger groups than is the case with face-to-face meetings, in which only one person is supposed to speak at a time.

According to Karacapilidis and Pappis (1997) the purpose of GDSS is to augment the effectiveness of decision groups through the interactive sharing of information between the group members and the computer.

2.2.5.3. The Advantages and Disadvantages of GDSS

There are many advantages and disadvantages of GDSS. These can be listed as following (Aiken et al., 1995).

2.2.5.3.1. the advantages of GDSS

1. Anonymity: The ability to exchange ideas or preferences anonymously in a GDSS environment promotes increased paticipatition by group members and consequently more information is shared. Participants no longer fear ridicule due to "foolish" comments. The provision of anonymity allows participants to avoid the pitfalls or group think and conformance pressure; that is, individuals feel less compelled to conform with the group's or the boss's opinion.

2. Parallel Communication: In oral meetings, people must listen to others speak and can not pause to think; a GDSS allows everyone to "speak" in parallel (typing and exchanging written comments simultaneously through the computer network). In a typical oral meeting, each person has only a few minutes to express ideas rather than throughout the entire meeting as when using a GDSS. Also, a few group members may "filibuster" or monopolize the available speaking time in an oral meeting preventing others from contributing their ideas.Parallel communication also contributes to increased participation and group synergy. Group synergy occurs, because other group members will be able to use an idea in a manner that the originator did not anticipate, because participants have different levels of information skills.

3. Automated Record Keeping: A GDSS automatically records comments, votes, and other information shared by a group onto a disk file. This automated log of the discussion supports the development of an organizational memory from meeting to meeting. Also, it is no longer necessary to take notes manually or mentally keep track of what was said. The participants in an oral meeting sometimes forget what was said earlier in the meeting and may consequently forget to make their intended comments on the subject. In a GDSS meeting, the participants simply enter their comments when they think of them.

4. More Structure: A GDSS may provide more structure and focus to a meeting making it more difficult to deviate from the problem-solving cycle and make incomplete or premature decisions. GDSS groups stay focused on the issues at hand and there is minimal non-task or social interaction.

5. Other Benefits: Because of anonymity, parallel communication, and automated record keeping, other GDSS benefits have arisen. Using GDSS, groups have experienced greater satisfaction with meetings and greater productivity by decreasing total meeting time and making better decisions.

2.2.5.3.2. The Disadvantages of GDSS

Although using a GDSS results in many advantages, there are also some disadvantages listed as following:

1. Slow Communication: Most people type slower than they speak, and in some cases, group participants may be unable to type at all. Most people would rather talk than type. Because talking is faster than typing, it is generally more efficient to use a GDSS only for larger groups (unless some other feature such as the provision of anonymity is especially important). When groups reach a size of eight to ten people, the advantage of parallel communication tends to outweigh the disadvantage of slow typing, and the use of a GDSS becomes more efficient.

2. Resistance to Change: People are sometimes intimidated by computers and feel threatened if forced to use them in a new meeting environment. Also, using the GDSS involves some training in the use of the software and some people may be resistant to learning how to use the system.

3. Lack of Media Richness: Because of a GDSS meeting relies primarily on written information, other forms of communication are minimized. For example, body language and facial expressions can help group members determine if a comment is meant to be funny or sarcastic in an oral meeting, but this media richness is lost in a GDSS meeting.

4. Possible Increase in Conflict: The use of GDSS may cause an increase in conflict and animosity due to anonymity in the meeting. Participants may be unnecessarily contemptuous of some of the ideas and may be overly critical in their comments. Personal attacks may be made easier with the provisions of anonymity resulting in hurt feelings and bitterness.

5. Possible Loss of Some Key Participants: Some people who normally dominate a verbal meeting may tend to "drop out" of electronic meetings because they are unable to use their strong verbal skills, although shyer people may participate more.

6. Misuse of Technology: One person in meetings utilizing the technology at Lante Corporation submitted multiple comments during the electronic discussion, simulating multiple participants. Thus, he was able to make it seem as if more people were agreeing with his idea than actually were. Because comments are anonymous, it is difficult to prevent such misuse.

7. Costs: A GDSS facility could involve a considerable monetary commitment and may not be cost efficient unless it gains acceptance and is used regularly and properly. The most Widely used commercial GDSS products range in $15000 to over $50 000. Hardware, net Work software, and other costs may be even higher.

As a consequence of these disadvantages, most meetings should probably not completely rely upon the technology.

2.2.5.4. Features of GDSS Support

2.2.5.4.1. Decision making support

Decision-making support begins with the features that have already been addressed with regard to all decision support systems. That is, GDSS must include access to models and model management tools, data and database management tools, and mail and management tools. However, groups generally are created to solve particularly poorly structured problems often with strategic or long-term implications. Hence, GDSS need to provide particular support for alternative generation. Alternative generation requires an electronic

brainstorming tool that records ideas or comments about ideas. Alternative generation, analysis and categorization can be quite difficult in a group setting, because everyone wants to participate at once and because participants follow different thought processes.
GDSS tools can provide the distinctive feature of parallel communications or the ability for group members to communicate information simultaneously.
Another way in which GDSS provides decision support is by acting as a group memory. In particular, it provides an electronic record of the meeting, both in summarized and raw form. This allows individuals who want to review the process access to the concepts and alternatives that were identified as well as the flow of information being compiled by the group. In other words, not only can an individual get the overall impression of the meeting But he or she can follow the exchanges to determine how final positions were derived. These features will allow group members to examine information available to the group, Whether it was generated by the group itself or prepared externally and presented to the group (Sauter, 1997).

2.2.5.4.2. Process support

One of the main contributions provided by GDSS technology is support of the process. One GDSS process feature is that the technology allows greater flexibility in the definition of meetings. Often group members cannot attend all the same meetings. This aspect of group meetings is a growing phenomenon as more diverse individuals are brought together to work on projects. GDSS can be extended for use in different places and at different times.
Group members might meet at the same time, but in geographically different locations joined through teleconferencing. With GDSS, people might meet in the same place but at Different times, and also GDSS allow the group members to meet at different times in different places.
A second process feature allowed by GDSS is the anonymity feature. The anonymity feature allows for a more democratic exchange of information because individuals must evaluate information on its own merits, not on what seems politically most expedient. With a GDSS an environment can be created in which group members participate equally, vote their conscience, and participate more often than they might in a no computerized environment where their contributions are more easily identified (Sauter, 1997).

2.2.5.5. Conceptual Framework

Conceptually our approach for supporting the analysis of consensus relevant data in GSS can be divided into three phase processes (Ngwenyama et.al., 1996).

1. Pre-evaluation
2. Preference elicitation
3. Data analysis and reporting

The pre-evaluation phase encompasses three basic activities:

1. Selecting the alternatives for evaluation
2. Determining the evaluation criteria
3. Determining the threshold of agreement.

The first two activities are common to any group decision process and the third activity is concerned with defining the stopping rules for the process. The preference elicitation phase is concerned with ranking the alternatives and providing comparison data, data analysis and reporting. The third phase is concerned with analyzing the preference data elicited from the decision makers to identify their positions on the consensus map.

2.2.5.6. A Typical GDSS Architecture

Figure 2.5 presents a simplified GDSS architecture exhibiting the principal concepts present in modern Goss. Theoretical framework is aimed at providing a solid semantic theory of Goss based on the following assumptions.

1. There are multiple decision makers.
2. The geographical locations of the decision makers can be dispersed.
3. The decision interacts in a co-operative manner and in a trusting environment.
4. The group shares a common set of feasible decision alternatives.
5. Each decision maker has his/her personal objectives that reflect a priori values and aspiration levels.
6. When a consensus is not found, negotiable alternatives are co-operatively sought.

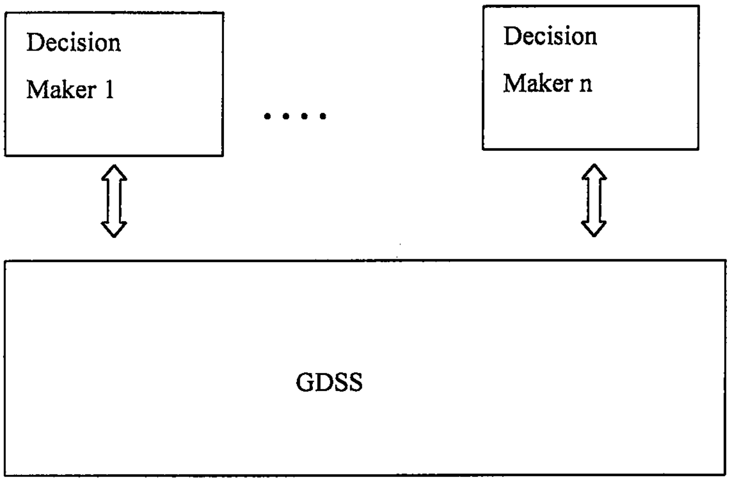

Figure 2 .5. A Typical GDSS Architecture

2.2.5.7. Flowchart of the GDSS Process

The GDSS, which was developed, by Easley and Mackay (1995) is described in the flowchart in Figure 2.6. Given a set of n decision alternatives loaded in the program as visual images or descriptions in step 1. Preference ratio judgments are collected from the group members. A full set is obtained if the n (n-1)/2 judgments per group member is not judged to be too many, otherwise a partial set is obtained. In step 2, the data are analyzed and a geometric representation, or configuration is estimated by maximum likelihood methods. This configuration specifies the locations of the alternatives, an ideal alternative for the group as well as a variance structure for each. In step 3, the group is shown this result using graphical images. In step 4, the estimated configuration is discussed by the group, focusing, for example, on interpretation of dimensions distances and variance magnitudes and any applications of the above for the group decision. If a decision can be made, this is done and the process ends, as in step 5.If the discussion leads to further clarification of some points or affects decision maker judgments the process is repeated as in step 6.

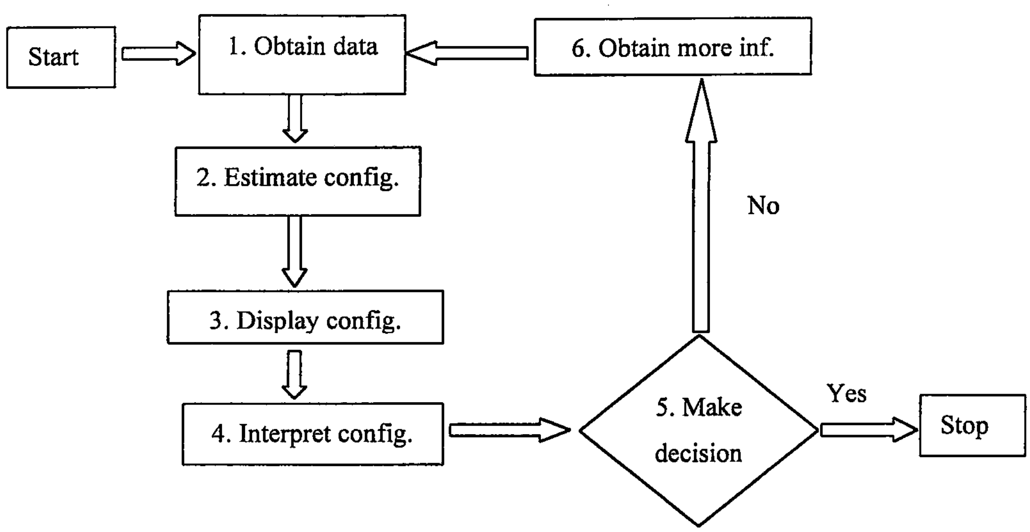

Figure 2.6. Flowchart of GDSS Process (Easley and Mackay, 1995).

2.2.5.8. GDSS Tools

According to Beruvides (1995) GDSS tools can be put into two categories (Figure 2.7).

Vision Quest	Group Systems
Brainstorming	Electronic Brainstorming
Comment Cards	Categorizer
Compactor	Vote
Point Allocation	Topic Commenter
Ranking	Group Dictionary
Rating	Alternative Evaluation
Scoring	Policy Formation
Subgroup	Group Writer
Voting	Idea Organization
	Group Matrix
	Stakeholder Identification
	Questionnaire

Figure 2.7 GDSS Tools (Beruvides, 1995).

2.2.6. Idea Generation Techniques

According to Aiken et al. (1996) Idea Generation techniques are :

1. Brainstorming: In a brainstorming meeting, a group takes turns contributing which are written down on a blackboard at the front of the room for all to see. Individuals are encourage

ged not to criticize ideas, but simply to contribute as many innovative ideas as possible, which will contribute to the solution of the problem.

2. Brainwriting: Brainwriting can be categorized as either interactive (face-to-face idea generation) or nominal (non face-to-face idea generation); it is characterized by silent, handwritten communication. The advantages of this technique over brainstorming are that individuals do not need to wait to speak (everyone can be writing at the same time), all ideas are recorded, and high degree of anonymity usually is preserved.

3. Electronic brainstorming: The term electronic brainstorming has been used to describe any form of electronic idea generation. However, it should be called electronic brainwriting.Electronic brainstorming can be classified into two categories.

a. Electronic individual pool writing: Electronic individual pool writing (also known as the electronic brain writing pool) is based upon the manual technique in which participants write comments on sheets of paper, which are then exchanged. The electronic version of the technique simply substitutes disk files for pieces of paper.

b. Electronic gallery writing: The electronic version of gallery writing substitutes one file for the many sheets of paper posted on the wall in the manual version. However, the electronic version preserves anonymity, unlike the manual version. Using electronic gallery writing, participants may submit typed comments and view all other members' submitted comments at any time.

2.2.7. Group Techniques and Processes

According to Guimaraes et al. (1997) Group Techniques and processes can be classified into following categories.

1. Brainstorming: Brainstorming is the most known method of idea generation and is in worldwide use. It is defined in the Webster's international Dictionary as: "to practice a conference technique by which a group attempts to find a solution for a specific problem by assuming all the ideas spontaneously contributed by its members". The technique employs four basic rules. Criticism is ruled out; "Free-wheeling" is welcomed (the wilder the idea, the better); Quantity is wanted (the greater the number of ideas, the more likehood of winners); Combination and improvement are sought. A number of modified brainstorming techniques have been devised.

2. The Delphi process: It is applied to complex and unstructured problems, in order to develop the strongest pro and con arguments for a set of alternative solutions. The Delphi process is based on individual and silent generation of suggestions and arguments, which are solicited by a facilitator to the group members. The phases followed by the facilitator are

1. Initial questionnaire,
2. Analysis of the questionnaire,
3. Second questionnaire,
4. Analysis of the second questionnaire and voting,
5. Third questionnaire and identification of agreements and disagreements,
6. Final report.

Delphi is based on the anonymity of the group members and is particularly oriented towards avoiding direct confrontation. Decisions with Delphi express opinions rather than facts, which requires group members to be experts. One other characteristic is that Delphi does not require physical presence.

3. The Nominal Group Technique: It is a participative data collection and consensus-forming device. The basic format of a NGT meeting is based on a facilitator, which ensures that the group development runs through the following phases:

1. Individual silent generation of a list of ideas;
2. Individual round-robin feedback, where each group member describes one idea from the individual list. A global list is then generated.
3. Group clarification of the ideas in the list, removing overlapped ones and clarifying any inconsistencies,
4. Individual voting and prioritizing of ideas,
5. Discussion of results, perception of consensus and focus on potential next steps.

The NGT meetings are designed to generate a high quality list of prioritized ideas but has been found to be very sensitive to the performance of the group facilitator.

4. The Survey technique: It allows managers to ask for information but make decisions alone. Subordinates may or may not be told about what the problem is. One major requirement is that the problem should be structured.

5. Voting: Voting is a group decision-making method in a democratic society, an expression of the will of the majority. It is a multiple criteria decision-making process whenever a voter casts a vote to select a candidate or alternative policy.

There are two basic voting systems: The non-ranked voting in which each voter has one and only one vote, and the preferential voting in which the voter indicates in what order of Preference he/she would place the candidates. The first system is indicated when the number of candidates are two, and the second system when the number of candidates are more than two and it is necessary to protect the minorities and the spreading of representation over a reasonably wide range of interests.

2.2.8. Technological support for agenda building

GDSS related support to agenda building, are classified as following:

GroupSystems: Provide an agenda tool, which allows the facilitator to organise multiple meetings within folders and, for each meeting, define the sequence of problem-solving methods to invoke (e.g. electronic brainstorming, categorizer, vote and so forth). The agenda also provides some additional facilitation aids, with elements such as introduction, lunch and coffee break. Using the agenda, the facilitator can also name and describe agenda topics, define time limits and select participants. Version 2.0 also provides a set of pre-defined agendas.

Meeting Works. It has an agenda planner, where topics and tasks can be organised in a list. Meeting Works separates the roles of agenda planner and meeting chauffeur. The later is responsible for matching agenda tasks with the problem-solving methods supported by the system. Another notable characteristic of Meeting Works is that it provides a small set of pre-defined agendas: group development, checkpointing, new project, and strategic planning.

Graphic facilitation A set of symbols, pictographs and ideographs that visually organise meetings.

Although GroupSystems and Meeting Works offer pre-defined agendas, they have low reuse potential and thus are mostly beneficial to expert facilitators. Furthermore, none of the above tools support the notion of design patterns.

Distributed Facilitation System: Research prototype addressing several facilitation functions necessary before, during and after meetings. Although pre-meeting support was not the focus of research, two functions were identified as indispensable to facilitators: tool selection and handle logistics. Other functions with low level of control from facilitators (high level of control from meeting leaders) are meeting goals, review previous meetings, gather documentation, develop rooster and inform participants.

1. **Expert System Planner** It is a prototype expert system designed to support GDSS facilitators during pre-meeting planning. The authors refer that various models of task characteristics, nature of the problem and other characteristics such as need for consensus are included in the system. Based on these models, the system makes tool recommendations to the facilitator. Contrary to the previous set of tools, one can find that this new set embeds in its functionality the notion of how the decision-making process should evolve. On the negative side however, we realise that the expert system approach followed by ESP does not allow facilitators to recognise and interpret the decisions made by the system (Antunes et al., 2001).

2.2.9 GDSS electronic facilitation support

Group Systems: These systems provide an agenda tool, which allows the facilitator to organize multiple meetings in folders and, for each meeting, define the sequence of problem-solving methods to invoke (e.g. electronic brainstorming, categorizer, vote and so forth). The agenda also provides some additional facilitation aids, with elements such as introduction, lunch and coffee break. Using the agenda, the facilitator can also name and describe agenda topics, define time limits and select participants. During meetings, and maintaining our focus exclusively on electronic facilitation, shift task is the most useful Group Systems' functionality. Shift task transfers data from one problem-solving method into another. One more functionality worth mentioning is the opinion meter. The opinion meter is a lightweight voting mechanism that allows fast decisions any time during meetings. Concerning post-meeting activities, Group Systems provides meeting reports and logs.

Meeting Works: It provides an agenda planner, where topics and tasks can be organized in a list. It has an interesting timer, which allows the facilitator to control tasks duration. Meeting Works separates the roles of agenda planner and meeting chauffeur. The later is responsible for matching agenda tasks with the problem-solving methods supported by the system. One notable characteristic of Meeting Works is that it provides a small set of pre-defined agendas: group development, check pointing, new project, and strategic planning (we have recently received the latest version of Group Systems Workgroup Edition 2.0, which also provides a small set of pre-defined agendas).

Distributed Facilitation System: Research prototype addressing several facilitation functions during meetings, classified as recording (transcripts, snapshots and summary), monitoring and process (start/stop). Other facilitation functions include start-up (enroll participants) and wind-up (tracking accomplishments).

Expert System Planner: It is a prototype expert system designed to support electronic facilitators during pre-meeting planning. The authors refer that various models of task characteristics, nature of the problem and other characteristics such as need for consensus are included in the system. Based on these models, the system makes tool recommendations to the facilitator.

The Matcher: It was designed to interconnect workflow and GDSS systems. The Matcher is responsible for the identification of situations where workflow systems cannot progress and informal decisions must be taken. The tool has a set of models that allow selecting the type of decision-making process most adequate to the situation. Group Work Environment. One component of GWE is the consensus support prototype, dedicated to assist facilitators in analyzing group status through preference elicitation and analysis of a set of alternatives. Preference data is analyzed using two metrics, participants' consensus and agreement.

Expert Session Facilitator: It is a prototype expert system designed to support GDSS facilitators during meetings. The system monitors the number of comments from each user and sends reminders to contribute more. When comments drop off, the system supplies an Indication to the facilitator.

2.2.10. Other facilitation support systems and tools

Meeting scheduling systems as, for instance, Lotus Notes and Ms. Outlook provide pre-meeting support with a set of common characteristics: a calendar, and means to visualize others' agendas, invite meeting participants and automatically schedule sessions. The following tools provide some computational support to facilitators during meetings:

1.Consensus Response Keypad: An interactive tool, which assures equal participation using question/ answer, inquiries, rankings and other games.

2.Council2: Allows gathering ideas fast and at any moment during a meeting.

3.DataBack, Wireless Response System and Innovator: Multiple choice voting systems for teamwork.

4.Facilitate.com (previously CA Facilitator.)

Other non-electronic systems can also be identified in this category:

a. Facilicom: A facilitators' support kit, with a set of components, which can be placed in chalkboards or flip charts during meetings.

b. Graphic facilitation: A toolbox of symbols, pictographs and ideographs, to visually organize meetings.

c. Gameshow Pro 2 and Game show P.A.L.: Games oriented towards team learning and teambuilding.

d. Thunderbolt Thinking: An activity package for group thinking.

2.2.11 Applications of GDSS

There are a lot of studies relating to GDSS in the literature. Blanning and Reinig (2001) applied GDSS to analysis of Hong Kong monetary policy. In the research a method for using GDSS was presented to acquire local information about politically sensitive events. The events of interest had three characteristics. First, they either occurred or didn't occur within some specified time frame, so it had to be known the probability of their occurrence. Second, their occurrence or nonoccurrence is dependent on certain political actors who had been identified. Third, there were certain knowledgeable people whose opinions would be useful in identifying the actors and describing their impact on the event, but they might be reluctant to discuss the event openly. These people had become the participants in the GDSS. The local information consisted of three parts. The first was discussion among the participants concerning possible actors relevant to the event of interest. This was used to generate the list of principal actors. The second component estimated of the position, power and salience. The third component was a discussion of possible changes in the positions of the actors. This was used to perform sensitivity analysis of the impact of actor positions on the probability of the event. For modeling the political events, Prince method was used. At the end of the study it was understood that events were directly influenced by political actors. It was found that information about the influence of the political actors on the events was both valuable and difficult to acquire. The methodology presented in this research illustrated the use of information technology in creating an environment in which knowledgeable participants could interact to provide inputs for the analysis of a political event.

Another study which was made by Rapcsak et.al. (2001) was about the evaluation of tenders in information technology. Two case studies were described for evaluating tenders in information technology. These studies are made in public procurement process based on multiattribute group decision models and the software WINGDSS was used. Considering the 17 tenders, altogether 468 offers were handed in by 34 firms. The processing of the 468 offers meant such a big task that was not possible to be completed by traditional, not computer based evaluation methods within the 5-day deadline prescribed in this case. On the other hand, by the above data processing schedule, the accomplishment would have taken some hours. However, the program terminated with an error message during the first step. Investigation soon revealed the reason: Some of the firms reedited the EXCEL files, e.g., inserted rows, or wrote text in cells where a numeric expression was expected e.g., price, or answered to a yes or no question in three lines, etc. Thus, all the EXCEL files had to be checked and repaired manually. Despite the fact that correction of the files took 3 days, the evaluation was completed in time. During the second round, the quantity of new input data was considerably lower: Only about one-third of the competitors were invited to participate, and the number of criteria in a tender varied between five and eight. The subjective scores were provided by the decision-makers in Excel files, and the objective values were disposed in dBase format. After applying the utility functions on the objective values, the arising objective scores were entered into the WINGDSS software, along with the subjective scores. The total group scores were exported in dBase format, and the reference price N was determine- need based on the offer prices and total group scores for each tender. Finally, the adjusted prices were determined.

In 1998, 17 parallel tenders were considered, 168 offers were evaluated in one round by nine decision-makers with respect to 100–150 criteria. As it was stated earlier, the evaluation of the tenders in 1998 was accomplished by similar models built for those in 1997. However, some of the elements were changed. The evaluation consisted of one round thus; there was no prequalification process. Filtering conditions were set up not only for legal or economic and financial attributes, but for other properties of the firms e.g., number of employee, for technical parameters of the offered product e.g., speed of a printer and evidence of compliance with certain standards proven by certifications supplied. The main criteria were as in 1997: offer price, technical competence, and product quality, but the criterion tree constructed for the purpose of evaluating 'product quality' and 'technical competence' was larger: 100 to 150 sub criteria were used in the various tenders. Almost all of the criteria were objective, scored by nearly 1500 utility functions. With respect to the subjective criteria, the 168 offers of the firms were scored by nine decision-makers, but by consensus rather than individually from our point of view, this meant that these criteria acted as objective ones as well. The evaluation was concluded with the price adjustment. Gaining experience from the tendering process in 1997, the offer data were requested in written form only, and professional operators were hired to type those in Access databases. As the utility functions could be sorted in some classes e.g., linear, piecewise linear, threshold, Boolean, they, too, were written in an Access database with a specific notation system, and a small interpreter program was developed to carry out the evaluation. With these arrangements, the evaluation of the 168 incoming offers was executed in 3 days (Rapcsak et.al., 2001).

Tavana et.al. (1996) made a study about an application to the ranking of nurse manager candidates at a hospital in the U.S. The decision-making group included staff nurses, nurse managers, and nursing directors. First, the group (12 decision members) articulated the criteria to be used in hiring a nurse manager. The decision makers were asked to provide a list of hiring criteria using a questionnaire that assured each respondent confidentially and anonymity. Then AHP was used to asses the relative importance of the various criteria and sub criteria and to evaluate available candidates on the hierarchy of criteria and sub criteria.

Later, Delphi principles of anonymous feedback and iterative revision were employed to help each decision maker to understand and respond to the judgments of the other decision makers. Maximize Agreement Heuristic (MAH) was used to produce a consensus ranking of the candidates from the individual decision makers.

Aiken et al. (1995) made a study about a Korean group Decision Support System. It was demonstrated how groups of Korean students used a GDSS developed at the university of Missisipi to exchange comments in Korean and English anonymously and simultaneously.

The study found no significant differences between the English and Korean systems in terms of self-assessed ratings of evaluation apprehension and production blocking and process satisfaction.

2.2.12. Conclusion

GDSS represents a hybrid technology, combining DSS and groupware technologies. It should have the components of a DSS. A typical GDSS consists of networked computer terminals, with a terminal for each group member. Group members interact electronically through communication of text, graphics, video or voice based information or through a combination of electronic and face-to-face interaction (Sosik and Avolio, 1998).

Consequently GDSS consists of hardware, software, and procedures for facilitating the generation and evaluation of alternatives as well as features for facilitating to improve group dynamics.

2.3. MULTIPLE CRITERIA DECISION MAKING (MCDM) AND SOME OF THE MULTIPLE ATTRIBUTE DECISION MAKING (MADM) METHODS

2.3.1. Multiple Criteria Decision Making

Many important decisions in organizations are made not only by an individual, but also by groups of individuals. Managers spend much of their time in decision related meetings. Balancing tradeoffs between objectives is even more important in groups than for individuals, because conflicting objectives and opposing viewpoints are inevitably going to exist. Decision making groups can range from cooperative, with very similar goals and outlooks, to antagonistic, with diametrically opposed objectives. Even in cooperative groups, conflict can arise during the decision process. If group members have different viewpoints, some method of aggregating preferences and reconciling differences are needed. Multi-criteria decision making (MCDM) methods have been developed to solve conflicting preferences among criteria for single decision makers (Davey and Olson, 1998). Multi criteria decision-making refers to making decisions in the presence of multiple objectives (Huang et al., 1995).

The process of decision-making is the selection of an act or courses of action from among alternative acts courses of actions such that it will produce optimal results under some criteria of optimization. This concise definition of decision-making invokes further elaboration to a certain extent. Before the problem can be considered well defined, the set of alternatives and the set of criteria have to be known and established first; only then can the selection process commence. What makes multiple criteria decision-making complex is the plurality of the criteria involved in the problem. In a single objective problem, the selection process can be managed with relative ease even if there are a large number of alternatives. As a matter of fact, solution procedures for single criterion decision problems with several alternatives are widely available. The degree of difficulty of decision-making is far more sensitive with the number of criteria (Tabucanon, 1988).

In decision analysis of complex systems, such term as “multiple criteria”, “multiple objectives” or “multiple attributes” are used to describe decision situations. Often these terms are used interchangeably. Certainly there are no universal definitions of these terms. Multiple criteria decision making (MCDM) has seemed to emerge as the accepted nomenclature for all models and techniques dealing with multiple objective decision making (MODM) or multiple attribute decision making (MADM). These are two brand categories of MCDM problems. MODM methods are often used with reference to problems with large set of alternatives, while MADM methods are meant to select the best from a small explicit list of alternatives. MODM therefore is a problem of design and mathematical techniques of optimization are needed in solving it. On the other hand, MADM is a problem of choice and classical mathematical programming tools need not to be used (Tabucanon, 1988).

Among alternative decision support methodologies, the techniques of multiple criteria decision making (MCDM) are exceptionally suitable for group settings. This is because the joint preference representations of MCDM tools not only accommodate multiple views on qualitative and quantative criteria, but also reveal areas of disagreement and help the group members clarify their viewpoints

2.3.2. Definitions related to MCDM

2.3.2.1. Attributes:

This term refers to descriptors of objective reality. They may be actual objective traits, or they may be subjectively assigned trait, but they are perceived as characteristics of objects in the outside world (They include our own descriptions of ourselves.). Thus, although they can not be seperated from the decision maker's values and model of reality, they can be identified and measured in relative independence from the decision maker's needs or desires (Zeleny, 1982).

According to Tabucanon, (1988) attributes are characteristics used to describe a thing. They can be objective traits such as age, wealth, height, weight etc. or they can be subjective traits such as prestige, goodwill and beauty.

2.3.2.2. Objectives:

Objectives are aspirations that also indicate directions of improvement of selected attribute such as maximize profit; minimize losses etc. (Tabucanon, 1988).

2.3.2.3. Goals:

While objectives are aspirations without the decision maker specifying their levels, goals are aspirations with given " a priori" levels of attributes desired. For example, the statement "to meet the sales quota of 10 tons for each product" means that the sales goal is 10 tons and this level has been prespecified (Tabucanon, 1988).

2.3.2.4. Criteria:

Criteria are measures, rules and standards that guide decision-making. Since decision-making is conducted by selecting or formulating different attributes, objectives or goals, all three categories can be referred to as criteria (Zeleny, 1982).

2.3.3. Relation between GDSS and MCDM

The obvious obstacle when multiple persons are involved in a joint decision problem is the fact that each individual has his/her own perception of the problem and accordingly the decision outcome. Therefore, in such an environment, it is common to encounter conflict between the opinions and desires of the group members. This conflict is referred to as interpersonal conflict and may arise due to the presence of numerous factors such as different values and objectives, different criteria and preference relations, lack of communication support between the members of the group, etc. Whatever the origin of the conflicting value systems, they usually affect the evolution of the decision process in ways that were not expected at the outset. Multiple criteria decision aid (MCDA) methods may be a useful tool in coping with such interpersonal conflicts where the aim is to achieve consensus between the group members or at least attempt to reduce the amount of conflict by concessions (Matsatsinis and Samaras, 2001).

Technology can support group work in four ways:

1. Structuring group processes,
2. Supporting communication,
3. Providing enhanced information processing,
4. Providing modeling capabilities

MCDM methods provide an elegant framework for three important GDSS tasks:

1. Representing multiple viewpoints of a problem,
2. Aggregating the preferences of multiple decision makers according to various group norms,
3. Organizing the decision process.

MCDM provides a simple but structured framework for controlling the decision-making process while the simplicity of MCDM outputs makes it easier to communicate, coordinate and aggregate individual analyses in the group decision-making process.

The multiple criteria process of a GDSS is the crucial aspect of the system because it provides a structured and integrated framework for alternative and criteria assessment and solution compromise. However, a problem arises when aggregating the preferences of a group of individuals to construct a joint decision model. Despite the impossibility of defining an axiomatic fair group solution without resorting to dictatorship, MCDM methods present a number of advantages for the group decision context:

1. By their nature, they integrate multiple views of the problem, using quantitative as well as qualitative criteria,
2. The interactive nature of many MCDM methods allows easy revisions of individual or group problem representations and opinions,
3. MCDM methods support democratic as well as hierarchical (or bureaucratic) group decision models.

Individual subjective assessments can be aggregated and processed by a decision analysis algo rithm and this in turn facilitates resolution of conflicts among group members and helps to achieve an acceptable compromise. The combination of various aggregation techniques could be used as an attempt to reduce the impact of the lack of a perfect group technique.

MCDM is one of the most dynamic areas of research oriented towards the understanding and support of decision making in general, and in group decision-making and negotiation in partic ular. MCDM provides a framework for group decision and negotiation support that may be oriented around the spaces where individuals can make decisions, in which the decisions can be evaluated and compared by an individual or by the group (Matsatsinis and Samaras, 2001).

2.3.4. Interactive Procedures for a MCDM

There are interactive procedures for solving a multiple criteria group decision-making (MCGDM) problem with incomplete information when multiple decision makers are involved. It is difficult for group members participating in the decision making process to articulate their preferences with cardinal values. Therefore, it was represented their preferences with. utility ranges obtained by solving linear programming (LP) problems with incompletely specified information, found conflicting judgments, if any in their specified information, and suggest interaction processes to help the group reach a consensus.

Kim et al. (1998) made a study about an algorithmic basis for a normative and interactive knowledge based group decision support system. They suggested a method for seeking consensus in a cooperative group decision context using incomplete information in order to reduce the burden on group members. A group decision-making process with incomplete information should provide refined frameworks for the following tasks:

1. Suggesting a preference. aggregation method among group members;
2. Establishing dominance conditions for group decision making based on the concept of individual pair wise dominance
3. Discovering conflicting opinions of group members
4. Suggesting the interactive approach which is most robustly and effectively useable, especially by nonexperts in multiple criteria decision-making MCDM methodology.

They suggested frameworks to support the above tasks under the following assumptions. It was considered a group decision problem in which a group with K members evaluates a finite set of M alternatives characterized by a finite set of N criteria.

A classical evaluation of alternatives leads to the aggregation of all criteria into a unique criterion called a utility function. The criteria are assumed to be preference independent, leading to an additive multiple criteria utility function. These assumptions include that individual weights, criteria weights, and individual utilities can be elicited directly from group members. In real world application, it is difficult to get exact parameter values from group members. Therefore, it was necessary to suggest a method of preference aggregation and ranking conditions for group decision-making using incomplete information on parameters (Kim et al., 1998).

In this study as an illustration, a husband and wife wish to purchase a car from a group of three cars. The selection was to be based on three criteria: safety, cost and attractiveness. The information on the two members' utility values was different. In the context of cars under consideration, the husband considered safety more important than cost, and cost more important than attractiveness. The wife feeled that safety was more important than cost; and that cost was as important, but no more than two times as important as attractiveness.

Under constraints on each member's utility values, it was calculated minimum and maximum values by solving 36 LP problems on each alternative The values in representing each member's aggregated ranges of alternatives, were obtained by individually solving minimization and maximization LP problems of weighted-sum under weights' constraints (Kim et al., 1998).

At the end of the study, it was suggested interactive procedures for a utility range based preference aggregation method, and pair wise dominance conditions for MCGDM without knowing exact parameter values. Procedures might be well suitable to situations in which we couldn't determine group members' importance weights and get exact criteria's weights whether the same criteria were considered or not. This study presented tools for implementing a GDSS, which would be a more reasonable approach in such a manner that decision makers could contribute their knowledge in cognitively comfortable view (Kim et al., 1998).

2.3.5. Applications of MCDM methods in group decision-making

From a methodological point of view, one can argue that all known group decision-making processes consist of four elementary stages:

1. An initialization stage, where the general rules of the decision process to follow are determined. Critical variables of the process such as the set of decision alternatives, the set of the evaluation criteria, the power coefficients of the group members, the rules that settle the successful or unsuccessful end of the process are usually determined in this stage.

2. A preference elicitation stage, where each individual group member states (explicitly or implicitly) his or her preferences on the decision alternatives. By applying a single decision maker multicriteria method, these preferences are transformed to an aggregated measure (a utility function for example) that reflects the individual's point of view on the decision outcome.

3. A group preference aggregation stage, where a synthesizing mechanism is used in order to derive a tentative collective decision, by absorbing, in some way, the individual opinions.

4. A conflict-resolution stage, in which an effort to reach consensus (unanimous agreement) or at least attempt to reduce the amount of conflict between individual opinions is performed, usually by group interaction through information exchange or by guiding the process to a previous stage (problem reconsideration) (Matsatsinis and Samaras,2001).

NEGO the negotiating process is a process of contracting and expanding sets of alternatives. Negotiations are carried on in the decision and/or objective spaces, since individual and joint rationality are not assumed, thus providing a more general concept than the utility concept. It is assumed that the set of alternatives is a convex polyhedron defined by a set of hard constraints. Negotiations begin by defining individual optimal alternatives for each decision maker along with aspiration levels. NEGO exerts pressure on decision makers through evaluating their concessions. It compares concessions made in two consecutive iterations and advises that all decision makers are getting closer to a consensus. It also compares concessions made by all decision makers taken together and advises if the whole group is getting closer to a consensus while moving from one iteration to another (Matsatsinis and Samaras, 2001).

2.3.6. Preference elicitation and evaluation techniques

Current preference elicitation and evaluation numerical techniques fall into one of four general categories:

1. Point estimates on interval scales;
2. Point estimates on ratio scales;
3. Interval estimates on ratio scales;
4. Interval estimates on interval scales.

More recently, point estimate techniques have been criticized for the following limitations:

1. They do not address the fuzziness, which is characteristic of many human decision making problems

2. It is very difficult to map qualitative preferences, which may have a range, to point estimates

3. Decision makers often operate in situations where incomplete information makes it impossible to assign point estimates to decision alternatives

4. In voting situations where coalitions may develop, point estimates can be manipulated

5. Aggregating the point estimates of individual decision makers to determine group preferences is problematic because, although individuals may agree on the qualitative rank of an object, they often disagree on the point estimate for it. However, many of these limitations can be solved by pair wise comparison techniques (Ngwenyama and Bryson, 1999).

2.3.7. Limitations in groupware approaches

Preference elicitation and evaluation approaches currently implemented in groupware are for the most part based on category 1 techniques. For example, Group System's (alias PLEXSYS, TEAM QUEST), Alternative Evaluation and Group Matrix tools both utilize a 10-point interval scale for rating evaluation criteria and decision alternatives. Vision Quest, another well-known GSS platform also uses a 10-point interval scale for the same purpose. These GSS platforms exhibit four basic limitations:

1. Lack of structured techniques for dealing with the problem of distinguishing among large numbers of alternatives. Thus, as the number of objects and evaluation criteria increases, it be comes increasingly difficult to rank them.

2.They do not elicit information on decision makers' preferences, which could be analyzed by facilitators and help, determine strategies for consensus formation.

3.They do not provide techniques for mapping qualitative criteria to numeric data for analysis.

4.Inadequate techniques for aggregating and analyzing individual preferences to facilitate consensus formation and for deriving group preference.

In general, these groupware present each decision maker with the decision alternatives (objects) and require the decision maker to order them in a manner consistent with his/her beliefs. In the case of scoring, each decision maker is presented with a list of alternatives, a numeric interval of values of the interval scale. The decision maker is then requested to assign an integer value from the relevant interval to each alternative. Apart from the extreme values on the scale, the meanings of the other values are usually not defined. Thus, it is possible that two different decision makers may associate two different meanings to the same numeric value. Similarly, a decision maker may associate the same meaning to two different values in the interval. These factors imply that the evaluation of the responses of the group in order both to determine the consensus response and the level of consensus is a problematic undertaking (Ngwenyama and Bryson, 1999).

Another important limitation is the approach to aggregating individual preferences into group preferences. The common technique used in groupware is arithmetic averaging, in which a group mean score/rank is derived. The deviation of each individual score from the mean is also computed. This information is then used to stimulate dialogue and bring the group members closer to the mean. The major problem here, however, is that a group mean is meaningless. For example, if the mean score is five for two decision makers who ranked decision alternatives on a ten point (0±9) scale; and the scores of both decision makers are equidistant from the mean (1, 9), the deviation of each decision maker from the mean does not in any way represent how far apart they are from consensus on the ranking of this decision alternatives (Ngwenyama and Bryson, 1999).

2.3.8. Multiple Attribute Decision Making (MADM) Methods

2.3.8.1. The Analytical Hierarchy Process (AHP):

The Analytical Hierarchy Process (AHP) is a decision-aiding method developed by Saaty, (1977). It aims at quantifying relative priorities for a given set of alternatives on a ratio scale, based on the judgment of the decision-maker, and stresses the importance of the intuitive judgments of a decision-maker as well as the consistency of the comparison of alternatives in the decision-making process. Since a decision-maker bases judgments on knowledge and experience, then makes decisions accordingly, the AHP approach agrees well with the behavior of a decision maker.

The Analytic Hierarchy Process (AHP) is a systematic procedure for representing the elements of any problem in the form of a hierarchy. The AHP supports executive decisions, communicates recommended decisions, applies knowledge, intuition and experience, derives priorities, and ranks alternatives. The AHP is a theory of measurement for dealing with quantifiable and intangible criteria, which has been applied to numerous areas, such as decision theory and conflict resolution. The AHP is based on the following three principles:

1. Decomposition,
2. Comparative judgments,
3. The synthesis of priorities.

The AHP starts by decomposing a complex, multi-criteria problem into a hierarchy where each level consists of a few manageable elements, which are then decomposed into another set of elements.

The second step is to use a measurement methodology to establish priorities among the elements within each level of the hierarchy.

The third step in using the AHP is to synthesize the priorities of the elements to establish the overall priorities for the decision alternatives.

The AHP differs from conventional decision analysis methodologies by not requiring decision makers to make numerical guesses, as subjective judgments are easily included in the process and the judgments can be made entirely in a verbal mode (Korpela and Lehmusvaara, 1999).

The Analytic HierarchyProcess (AHP) is a multiattribute modeling methodology, which was first developed and applied by Saaty.Since its introduction; many different problems of multi-attribute decision modeling have been successfully investigated with the mathematical techniques of this approach.

The application areas span from finance to land use planning. The Analytic Hierarchy Process is a compensatory multi-attribute approach that accommodate both qualitative and quantative factors. The decision problem is structured as a hierarchy with an overall goal or objective at the top of the hierarchy, followed by criteria and sub criteria at subsequent levels, and finally a set of decision alternatives at the lowest level of the hierarchy. Using a hierarchical structure permits inclusion of a large number of relevant criteria by decomposing them into sub criteria. This approach provides the opportunity to make meaningful comparisons among a relatively small set of criteria /sub criteria at a given level while achieving broad overall coverage. When the decision hierarchy is structured, the criteria, sub criteria and the alternatives are compared on a pair wise basis with respect to the element in the next higher level of the hierarchy using a 9-point scale. The pair wise evaluations are analyzed using Saatys eigenvector method to determine the priorities (weights) of the criteria, subcriteria and alternatives. Those priorities are synthesized to obtain overall priorities of the alternatives (Armacost et.al., 1999).

Four axioms apply to AHP and must be satisfied in order for conventional AHP to be valid. The four axioms are:

1. **Reciprocal condition:** When comparing two objectives, the intensity of preference of the opposite comparison is the reciprocal of the original comparison.
2. **Homogeneity:** Elements in a particular level of the hierarchy are comparable.
3. **Dependence:** Weights of higher-level elements do not depend on lower level elements.
4. **Expectations:** All criteria and alternatives are represented in the hierarchy.

2.3.8.1.1. Applications related to AHP.

There are numerous applications related to the AHP.

Byun (2001) shows the use of AHP for deciding on car purchase. The AHP model depicted by Byun (2001) uses the decision criteria such as exterior, convenience, performance, safety, economic aspect, dealer and warranty as well as 39 sub criteria. For the implementation of the AHP they were considered. By focusing on two issues a new methodological extension of the AHP was presented. One combined pair wise comparison with a spreadsheet method using a 5 point rating scale. The other applied the group weight to a reciprocal consistency ratio. Through the sensitivity analysis, the fact that model 1 ranked the highest is consistent with the result of the highest market share. This method for selecting the best car would be helpful to manufacturers and dealers.

There are limitations of the method. It depends on qualitative data in the evaluation of a car model by its owners. It would be better if convenience, comfort, visibility and performance of brake systems could be evaluated more objectively by means of the data obtained by the results of testing.

Armacost et al. (1999) showed the use of AHP to a situation involving a large nominal group of dispersed decision makers where the entire hierarchy is not defined at the outset. The approach was demonstrated and evaluated in a case study to select an alunmi anniversary gift to the U.S.cost guard academy with a large nominal group of decision makers dispersed throughout The U.S. The AHP was used as an integrative approach to identify the priorities of the various criteria and then used those priorities to screen and consolidate a large set of potential alternatives. The consolidated set of alternatives was evaluated by each individual in the group using AHP, and was combined using the geometric mean, and the results were synthesized to obtain the overall priorities of the alternatives.

2.3.8.1.2. Model Explanation and Calculations

The strength of this approach is that it organizes tangible and intangible factors in a systematic way, and provides a structured yet relatively simple solution to the decision-making problems. In addition, by breaking a problem down in a logical fashion from the large, descending in gradual steps, to the smaller and smaller, one is able to connect, through simple paired comparison judgments, the small to the large (Kamal M. Et al, 2001).

Saaty developed the following steps for applying the AHP:

1. Define the problem and determine its goal.
2. Structure the hierarchy from the top (The objectives from a decision-maker's viewpoint) through the intermediate levels (criteria on which subsequent levels depend) to the lowest level, which usually contains the list of alternatives.
3. Construct a set of pair-wise comparison matrices (size nxn) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement shown in Table 2.1. The pair-wise comparisons are done in terms of which element dominates the other.
4. There are n x (n-1)/2. Reciprocals are automatically assigned in each pair-wise comparison.
5. Hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken over all weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.
6. Having made all the pair-wise comparisons, the consistency is determined by using the eigenvalue lambda (λ) max, to calculate the consistency index, CI as follows:

CI = (λmax-n) / (n-1) where n is the matrix size. Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table 2.1 The CR is acceptable, if it does not exceed 0.10.or according to some sources 0.20.If it is more, the

Judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improve (Ahlatçıoğlu and Tiryaki, 2001).

7. Steps 3-6 are performed for all levels in the hierarchy.

Table 2.1 Pair wise comparison scale for AHP preferences

Numerical rating	Verbal judgments of preferences
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

Table 2.2 Average random consistency (RI)

Size of Matrix	1	2	3	4	5	6	7	8	9	10
Random Consistency	0	0	0,58	0,9	1,12	1,24	1,32	1,41	1,45	1,49

2.3.8.1.3. Application of the AHP in project management

Here, contractor prequalification (an evaluation problem) will be used as an example of the possibility of using AHP in project management. Prequalification is defined as the screening of construction contractors project owners or their representatives according to predetermined set of criteria deemed necessary for successful project performance, in order to determine the contractors' competence or ability to participate in the project bid.

A simplified project example of contractor prequalification will be demonstrated here for illustration purposes. To simplify calculations, the factors that will use in the project example for prequalification are experience, financial stability, quality performance, manpower resources, equipment resources, and current workload. Contractors are A, B, C, D and E. The matter is safeguarded by checking the consistency of the pair wise comparison, which is a part of the AHP procedure. By following the AHP procedure, the hierarchy of the problem can be developed. For step 3, the decision-makers have to indicate preferences or priority for each decision alternative in terms of how it contributes to each criterion.

Then, the following can be done manually or automatically by the AHP software,

1. Synthesizing the pair-wise comparison matrix

2. Calculating the priority vector for a criterion such as experience 3. Calculating the consistency ratio;

4. Calculating lambda max;

5. Calculating the consistency index, CI;

6. Selecting appropriate value of the random consistency ratio from Table 2.2, and

7. Checking the consistency of the pair-wise comparison matrix to check whether the decision-maker's comparisons were consistent or not. The calculations for these items will be explained next for illustration purposes. Synthesizing the pair-wise comparison matrix is performed by dividing each element of the matrix by its column total. For example, the value 0.08 in Table 2.4 is obtained by dividing 1 by 12.5, (the sum of the column items in Table 2.3 (1+3+2+6+1/2) by dividing 12,5)

Table 2.3 Pair wise comparison matrix for experience

Exp.	A	B	C	D	E
A	1	1/3	1/2	1/6	2
B	3	1	2	1/2	4
C	2	1/2	1	1/3	3
D	6	2	3	1	7
E	1/2	1/4	1/3	1/7	1
TOTAL	12,5	4,0833	6,8333	2,1429	17

Table 2.4 Synthesized Matrix for experience

Exp.	A	B	C	D	E	Pri.Vector	Wgh Sum	Lambda
A	0,080	0,082	0,073	0,078	0,118	**0,086**	**0,432**	**5,017**
B	0,240	0,245	0,293	0,233	0,235	**0,249**	**1,261**	**5,059**
C	0,160	0,122	0,146	0,156	0,176	**0,152**	**0,767**	**5,038**
D	0,480	0,490	0,439	0,467	0,412	**0,457**	**2,314**	**5,059**
E	0,040	0,061	0,049	0,067	0,059	**0,055**	**0,277**	**5,018**
Total	1	1	1	1	1	1,0000	λ max	**5,038**

We find the inconsistency index as follows:

CI = (Lambda max – n) / (n-1) (3.1)

CI=(5,038-5)/(5-1) = 0,095

Selecting appropriate value of random consistency, from the table, we find **RI=1,12**.and Then we calculate the consistency ratio

CR= CI / RI = 0,095/1,12 =0,085 < 0,1 (3.2)

The priority vector in Table 2.4 can be obtained by finding the row averages. For example, the priority of contractor A with respect to the criterion experience in Table 2.4 is calculated by dividing the sum of the rows(0,08+0,082+0,073+0,078+0,118) by the number of contractors (columns), i.e., 5, in order to obtain the value 0.086. The priority vector for experience, indicated in Table 2.5, is given below.

[0,086], [0,249], [0,152], [0,457], [0,055].

Dividing all the elements of the weighted sum matrices by their respective priority vector element, we obtain:

0,432/0.086=5,012, 1.261/0.249=5.056, 0.767/0.152=5.039, 2.314/0.457=5.059,

0,277/0.055=5.018.

We then compute the average of these values to obtain lambda(λ)max

λ max = (5.012+5.056+5.039+5.059+5.018) / 5= 5.037

Now, we find the consistency index, CI, as follows:

CI = λmax-n / n-1 =5.037-5/5-1= 0,00925.

Selecting appropriate value of random consistency ratio, RI, for a matrix size of five using Table 2.2, we find RI = 1.12. We then calculate the consistency ratio, CR, as follows:

CR=CI/RI=0.0925 / 1.12=0.0082.

As the value of CR is less than 0.1, the judgments are acceptable. Similarly, the pair-wise comparison matrices and priority vectors for the remaining criteria can be found as shown in the other tables.

Table 2.5 Pair wise Comparisons for Performance

FS	A	B	C	D	E
A	1	6	3	2	7
B	1/6	1	1/4	1/2	3
C	1/3	4	1	1/3	5
D	1/2	2	3	1	7
E	1/7	1/3	1/5	1/7	1
Total	2 1/7	13 1/3	7 4/9	4	23

λmax=5.32, CI=0,08, RI=1.12, CR=0,071 < 0,1 OK

Table 2.6 Pair wise Comparisons for Quality Performance

QP	A	B	C	D	E
A	1	7	0,3333	2	8
B	0,1429	1	0,2	0,25	4
C	3	5	1	4	9
D	0,5	4	0,25	1	6
E	0,125	0,25	0,1111	0,1667	1
Total	4,7679	17,25	1,8944	7,4167	28

λmax=5.38,CI=0.095,RI=1.12,CR=0.085<0.10 O.K.

Table 2.7 Pair wise comparison matrix for manpower resources (MPR)

MPR	A	B	C	D	E
A	1	0,5	0,25	2	5
B	2	1	0,3333	5	7
C	4	3	1	4	6
D	0,5	0,2	0,25	1	2
E	0,2	0,1429	0,1667	0,5	1
Total	7,7	4,8429	2	12,5	21

λmax=5.24, CI=0.059, RI=1.12, CR=0.053<0.10 O.K.

Table 2.8 Pair wise comparison for equipment resources (ER)

ER	A	B	C	D	E
A	1	1/6	1/8	2	3
B	6	1	1/4	5	7
C	8	4	1	9	9
D	1/2	1/5	1/9	1	2
E	1/3	1/7	1/9	1/2	1
Total	15,833	5,5095	1,5972	17,500	22,000

λmax=5:28, CI=0.071,RI=1.12,CR=0.063<0.10 O.K.

Table 2.9 Pair wise comparison for current work load (CWL)

CW	A	B	C	D	E
A	1	1/5	1/3	3	3
B	5	1	5	6	6
C	3	1/5	1	2	2
D	1/3	1/6	1/2	1	2
E	1/3	1/6	1/2	1/2	1
Total	9,6667	1,7333	7,3333	12,500	14,000

λmax=5.40,CI=0.10,RI=1.12,CR=0.089<0.10 O.K.

Table 2.10 Pair wise comparison matrix for six criteria

	EXP	FS	QP	MPR	ER	CWL
EXP	1	2	3	6	6	5
FS	1/2	1	3	6	6	5
QP	1/3	1/3	1	4	4	3
MPR	1/6	1/6	1/4	1	2	1/2
ER	1/6	1/6	1/4	1/2	1	1/4
CWL	1/5	1/5	1/3	2	4	1
TOTA	2,3667	3,8667	7,8333	19,500	23,000	14,750

λmax=6.31,CI=0.062,RI=1.24,CR=0.05<0.10 O.K.

Now, the Expert Choice software can do the rest automatically, or we manually combine the criterion priorities and the priorities of each decision alternative relative to each criterion in order to develop an overall priority ranking of the decision alternative, which is termed as the priority matrix. The calculations for finding the overall priority of contractors are given below for illustration purposes:

Overall priority of contractor A

=0.372x0.086+0.293x0.425+0.156x0.269+0151x0.053+0.039x0.084+0.087x0.144=0.222

Table 2.11 Priority matrix for contractor prequalification

Contractor	EXP (0,372)	FS (0,293)	QP (0,156)	MPR (0,053)	ER (0,039)	CWL (0,087)	PRI VECTOR
A	0,086	0,425	0,269	0,151	0,084	0,0144	0,222
B	0,249	0,088	0,074	0,273	0,264	0,537	0,201
C	0,152	0,178	0,461	0,449	0,556	0,173	0,241
D	0,457	0,268	0,163	0,081	0,057	0,084	0,288
E	0,55	0,039	0,031	0,045	0,038	0,062	0,046

Overall priority of contractor B = 0.201

Overall priority of contractor C = 0.241

Overall priority of contractor D = 0.288

Overall priority of contractor E = 0.046.

For prequalification purposes, the contractors are now ranked according to their overall priorities, as follows:
D, C, A, B, and E, indicating that D is the best-qualified contractor to perform the project. Contractor prequalification involves criteria and priorities that are determined by owner requirements and preferences as well as the characteristics of the individual contractors. AHP allows group decision-making. The method can also be implemented on computer.

2.3.8.2. REMBRANDT SYSTEM (Ratio Estimation in Magnitudes or deci-Bells to Rate Alternatives which are Non-Dominated)

2.3.8.2.1. Introduction

A group in the Netherlands led by F.A.Lottsma, has developed a system which uses **R**atio **E**stimation in **M**agnitude or deci-**B**ells to **R**ate **A**lternatives which are **N**on-**D**ominated. This system is intended to adjust for three contended flaws in AHP. First, direct rating is on a logarithmic scale, which replaces the fundamental 1-9 scale, presented by Saaty. Second, the Perron-Frobenious eigenvector method of calculating weights is replaced by the geometric mean which avoids potential rank reversal, and third, aggregation of scores by arithmetic mean is replaced by the product of alternative relative scores weighted by the power of weights obtained from analysis of hierarchical elements above the alternatives (Olson et al., 1995).

2.3.8.2.2 .REMBRANDT Scale and Computations

The Rembrandt system has been designed to address three criticized features of AHP. The first issue, addressed by Lootsma is the numerical scale for verbal comparative judgment. Saaty presented a verbal scale for the ratio of relative value between two objectives where 1 represents roughly equal value, 3 represents the base object as being moderately more important than the other object, 5 reflects essential advantage, 7 very strong relative advantage, and 9 the ultimate overwhelming relative advantage.

Lootsma feels that relative advantage is more naturally concave, and presents a number of cases where a more nearly a logarithmic scale would be appropriate such as planning horizons, loudness of sounds, and brightness of light.

Therefore Lootsma presents a geometric scale where the gradations of decision maker judgment are reflected by the scale as follows:

Table 2.12 Geometric scale presented by Lootsma (Olson et. Al., 1995)

1/16	Strict preference for object 2 over base object
1/4	Weak preference for object 2 over base object
1	Indifference
4	Weak preference for the base object over object 2
16	Strict preference for the base object over object 2

The ratio of r_{jk} on the geometric scale is expressed as an exponential function of the difference between the echelons of value on the geometric scale δ(jk) as well as a scale parameter y. Lootsma considers two alternative scales y to express preferences.

For calculating the weight of criteria, y=In √2=0.347 is used.

For calculating the weight of alternatives on each criterion, y = In 2 = 0.693 is used.

The difference in echelons of value $\delta_{(jk)}$ is graded as in Table 2.13, which compares Saaty's ratio scale with the REMBRANDT scale.

Table 2.13 AHP Scale and corresponding REMBRANDT scale

Verbal Description	Saaty Ratio(Wj/Wk)	REMBRANDT(δ(jk))
Very strong preference for object k	1/9	-8
Strong preference for object k	1/7	-6
Definite preference for object k	1/5	-4
Weak preference for object k	1/3	-2
Indifference	1	0
Weak preference for object j	3	2
Definite preference for object j	5	4
Strong preference for object j	7	6
Very strong preference for object j	9	8

The second suggested improvement is the calculation of impact scores. The arithmetic mean is subject to rank reversal of alternatives. The geometric mean is not subject to rank reversal, nor is logarithmic regression. Note that Saaty argues that rank reversal when new reference points are introduced is a positive feature. Barzilai, Cook and Golany (1987) taking an opposing view, argued that the geometric mean was more appropriate for calculation of relative value (through weights) than the arithmetic mean used by Saaty.

Lootsma proposes logaritmic regression minimizing $\Sigma_{j<k}(\text{In } r_{jk}\text{-In } v_j+\text{In } v_k)^2$ where r_{jk} are the ratio comparisons made by the decision makerfor base object j and compared object k, and the weight for j (Wj) is represented by In v_j Ratio v_{jk} is the ratio of Wj/Wk.The analysis is to calculate these weights. Since $r_{jk} = w_j/w_k$, error is represented by r_{jk} - w_j/w_k.The ratio comparisons made by the decision maker are observations and regression minimizing the squared error yields the set of weights w_i which best fit the decision maker expressed preferences. Solving this is complicated by the fact that the resulting data set is singular. However, a series of normal equations can be solved to yield the desired weights.

To demonstrate, assume a pair wise comparison ratio comparing three factors A, B and C where A is definitely preferred over B, A is strongly preferred over C, while B is weakly preferred over C. This yields the matrix δ(jk) of preferences ,transformed into r_{jk}=e $e^{0.3478(jk)}$. Weights are desired that minimize the function $\Sigma_{j=1,.n}\, \Sigma_{k=1,..n}\, (\text{In } r_{jk} \text{-}w_j\text{+}w_k)^2$. The ratio matrix in REMBRANDT for criteria is transformed through the operator e0.347 $^{r(jk)}$ to generate the set of values transformed to the logarithmic scale. The geometric means of row elements of such a matrix yields the solution minimizing the sum of squared errors of the form $\Sigma_{j=1,n}\, \Sigma_{k=1,n}(\text{In } r_{jk}\text{-}w_j\text{+}w_k)$. This yields the following:

	$\delta^{(jk)}$		$e^{0.3478(jk)}$			Geometric Means
0	+4	+6	1	4	8	3.175
-4	0	+2	0.25	1	2	0.794
-6	-2	0	0.125	0.5	1	0.397

This solution is normalized by product. It is a simple matter to normalize by the sum, simply dividing each element by the total.

The third improvement proposed by Lootsma is the aggregation of scores. This level is normalized multiplicatively, so that the product of components equals 1 for each of the k factors over which the alternatives are compared. Therefore each alternative has an estimated relative performance w_k for each of the k factors. The components of the hierarchical level immediately superior to this lowest level are normalized additively, so that they add to 1,yielding weights. (Olson et al., 1995).

2.3.8.2.3. An Application of REMBRANDT System

Example:

To demonstrate an example of an application of REMBRANDT, consider an analysis comparing three alternatives A, B, and C, over four criteria, W, X, Y, and Z. The hierarchy may be represented as following.

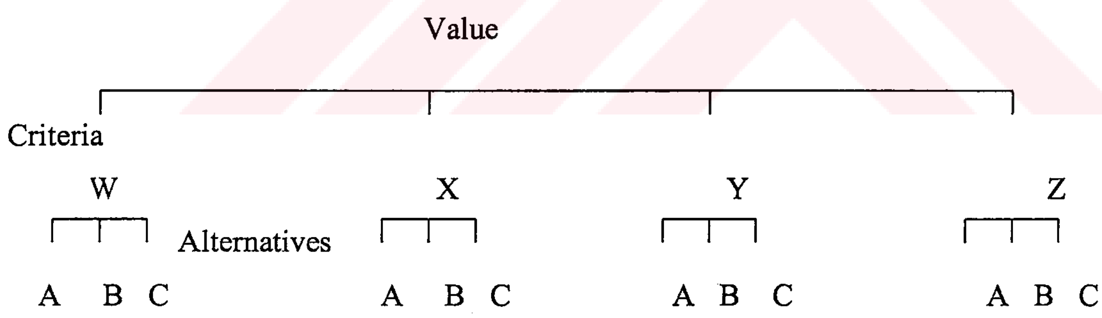

Figure 2.8. Hierarchy Tree

1. Criteria Calculations

Table 2.14 Pair wise Comparison of Criteria. According to AHP scale (Olson et al, 1995).

	W	**X**	**Y**	**Z**
W	1	1	5	7
X	1	1	1	3
Y	1/5	1	1	3
Z	1/7	1/3	1/3	1

The following matrices show the δ(jk) matrices equivalent to Saaty's scale and then later $e^{0.3478(jk)}$ is calculated and the scores from the row-wise geometric means and the additively normalized scores are obtained.

Table 2.15 Pair wise comparison of criteria according to Rembrandt scale (Olson et al, 1995)

	W	**X**	**Y**	**Z**
W	0	0	4	6
X	0	0	0	2
Y	-4	0	0	2
Z	-6	-2	-2	0

Table 2.16 Geometric Mean Calculation (Olson et al, 1995).

$e^{0.3478(jk)}$	W	X	Y	Z	Geo.mea	weights	
W	1	1	4	8	2,3784	**0,493**	**W**
X	1,0	1	1	2	1,1892	**0,246**	**X**
Y	0,25	1,0	1	2	0,8409	**0,174**	**Y**
Z	0,125	0,50	0,50	1	0,4204	**0,087**	**Z**
				Total	4,8290	1,000	

So above we found the weights of the criteria by using the geometric mean in the REMBRANDT which are:

The weight of criteria **W=0.493**

The weight of criteria **X=0.246**

The weight of criteria **Y=0.174**

The weight of criteria **Z=0.087**

The pair wise comparisons of alternatives A, B and C on each of the criteria are as following:

2. The Calculations of the Weights of the Alternatives

Alternatives are calculated as follows:

Table 2.17 Alternatives For Criterion W (Olson et al, 1995).

		A	B	C		A	B	C	Geo mean	Additive
	A	0	**4**	**6**	A	1	16	64	10,0794	**0,902**
W	B	-4	0	**4**	B	0,0625	1	16	1	**0,089**
	C	-6	-4	0	C	0,01562	0,0625	1	0,09921	**0,009**
								Total	11,1786	1,000

Table 2.18 Alternatives for Criterion X (Olson et al, 1995).

		A	B	C		A	B	C	Geo mean	
	A	0	**-2**	**1**	A	1	0,25	2	0,7937	**0,155**
X	B	2	0	**4**	B	4	1	16	4	**0,783**
	C	-1	-4	0	C	0,5	0,062	1	0,31498	**0,062**
								Total	5,1087	1,000

Table 2.19 Alternatives for Criterion Y (Olson et al, 1995).

		A	B	C		A	B	C	Geo mean	
	A	0	**0**	**-4**	A	1	1	0,0625	0,39685	**0,067**
Y	B	0	0	**-3**	B	1	1	0,125	0,5	**0,084**
	C	4	3	0	C	16	8	1	5,03968	**0,849**
								Total	5,9365	1,000

Table 2.20 Alternatives for Criterion Z (Olson et al, 1995).

		A	B	C		A	B	C	Geo mean	
	A	0	**1**	**-1**	A	1	2	0,5	1	**0,286**
Z	B	-1	0	**-2**	B	0,5	1	0,25	0,5	**0,143**
	C	1	2	0	C	2	4	1	2	**0,571**
								Total	3,5000	1,000

Aggregation is accomplished as following:

Table 2.21 Calculation of REMBRANDT

Alternatives Calculation Method	Value	Normalized
Value(A) = $10.0794^{0.493} x0.7937^{0.246} x0.3969^{0.174} x1^{0.087}$	=2.513	0.624
Value(B) = $1^{0.493} x4^{0.246} x0.5^{0.174} x0.5^{0087}$	=1.174	0.292
Value(C) = $0.0992^{0.493} x0.3150^{0.246} x5.0397^{0.174} x2^{0.087}$	=0.339	0.084

RESULT

These are aggregated to obtain weighted scores for each of the alternatives A, B and C as shown in Table 2.22.

Table 2.22 Results of REMBRANDT

Alternatives	Value	Normalized Value
A	2,510	0,624
B	1,174	0,292
C	0,339	0,084

The scores reflect relative value,however,REMBRANDT uses a larger scale than AHP,resulting in greater interval distance (Olson et al,1995).

Alternative A is 2.14 times as valuable as alternative B ,and 7.43 times as valuable as alternative C.

2.3.8.3. THE ELECTRE METHOD (ELimination and (Et) Choice Translating REality)

2.3.8.3.1. The ELECTRE SYSTEM

As part of a philosophy of decision aid, ELECTRE (in its various forms) was conceived by Bernard Roy in response to deficiencies of existing decision making solution methods. We shall consider only the ELECTRE methods. Roy's philosophy of decision aid is well expounded in Roy (1993, 1996). Moreover, of the different versions of ELECTRE which have been developed (I, II, III, IV and TRI), we shall use the method specifically referred to as ELECTRE III. All methods are based on the same fundamental concepts, as explained subsequently, but differ both operationally and according to the type of decision problem.

Specifically, ELECTRE I is designed for selection problems, ELECTRE TRI for assignment problems and ELECTRE II, III and IV for ranking problems. ELECTRE II is an old version; ELECTRE III is used when it is possible and desirable to quantify the relative importance of criteria and ELECTRE IV when this quantification is not possible).

Here, we will handle project ranking problem while explaining the ELECTRE Method.A number of factors influenced the specific selection of the ELECTRE III method for the project ranking problem. Originally, it was the intention of Northern Generation to use AHP to rank projects; however for eighty projects the number of pair wise comparisons required by AHP was prohibitive. Secondly, ELECTRE was originally developed by Roy to incorporate the fuzzy (imprecise and uncertain) nature of decision-making, by using thresholds of indifference and preference. A further feature of ELECTRE, which distinguishes it from many multiple criteria solution methods, is that it is fundamentally non-compensatory. This means, in particular, a very bad score on a criterion cannot be compensated by good scores on other criteria. A further original feature is that ELECTRE models allow for incomparability. Incomparability, which should not be confused with indifference, occurs between any alternatives a and b when there is no clear evidence in favor of either a or b. Finally, the choice of ELECTRE III was also influenced by successful applications of the approach

2.3.8.3.2. Concepts

Two important concepts that underscore the ELECTRE approach, thresholds and outranking, will now be discussed. Assume that there exist defined criteria, gj, j = 1, 2, …,r and a set of alternatives, A. Traditional preference modelling assumes the following two relations hold for two alternatives (a, b).

a**P**b (a is preferred to b) $g(a) > g(b)$

a**I**b (a is indifferent to b) $g(a) = g(b)$

Now we show the successful use of ELECTRE III, for ranking the minor projects at Northern Generation.

The project ranking decision problem

This project ranking problem is, like many decision problems, challenging for at least two reasons. First, there is no single criterion that adequately captures the effect or impact of each project; in other words, it is a multiple criteria problem. Second, there is no single decision maker; instead the project ranking requires a consensus from a group of decision makers. Buchanan et. al. (1998) have argued that good decisions will typically come from a good decision process and suggest that where possible the subjective and objective parts of the decision process should be separated. A decision problem can be conceived as comprising two components; a set of objectively defined alternatives and a set of subjectively defined criteria. The relationship between the alternatives and the criteria is described using attributes which describe, as objectively as possible, the features of alternatives that are relevant to the decision problem. Attributes form the bridge between the alternatives and the criteria. Each criterion attempts to reflect a decision maker's preference with respect to certain feature of the decision problem. These preferences, being specific to a decision maker, are subjective. The elaboration of criteria from attributes is therefore, a necessarily subjective process.

The goal of structuring the decision problem into objective and subjective components places a clear boundary around the preferences of the decision maker(s). It also allows the evaluation of alternatives (in terms of attributes) to be undertaken as objectively as possible. Moreover, it is generally accepted that any structuring of a decision problem should enhance the decision process and improve the quality of the outcome

Northern Generation clearly defined the alternatives and criteria by using project ranking problem (Buchanan et. Al., 1998). They are specific projects, such as:

- Penstock and Power Station Area Rock Stabilization,
- Automatic Generator Control,
- Lower Station Electrical Upgrade, and
- Station Forced Ventilation.

After discussion with the management team, the following five criteria were used to evaluate the projects (with some attributes shown in brackets):

FI financial (cost and financial return)

SD solution delivery (consequences of poor implementation and "provenness" of the technology)

SC strategic contribution (contribution to the business plan)

RM risk management (risk of plant failure and damage following natural disaster), and

EN environmental (effect on relationship with resource partners and access to resources).

The scores for the criteria are arbitrarily scaled from 0 to 100; the units of these criteria are not meaningful outside this application. The actual scores for each criterion, with the exception of Strategic Contribution (SC) are defined by a number of attributes to describe the performance of the project. For example, the risks introduced by a particular project may influence generation revenues, station staff and the public-at-large. The magnitude of generation revenues at risk is then a function of the particular generating station and the number of generating units affected. In each case a logical formula is defined to produce the score for each criteria. This input, where each project is assessed across each criterion, produces a matrix of impacts or performances. The evaluation of the projects on the attributes was performed as objectively as possible (in cooperation with some experts who were familiar with the project detail). The process of aggregating attributes into criteria involves a first level of subjectivity.

At this level, it is important that criteria and the way they are elaborated are accepted by the various decision makers; in the case the sponsors of each maintenance project. The set of criteria was thus validated when they could form a common basis for discussion and evaluation. A second level of subjectivity, taken into account in a later stage of the approach, deals with preference information, which reflects, for example, the relative importance of each criterion. Here, each decision maker has the opportunity to express his/her own view so as to confront the different value systems at stake. Table 3.23 provides a simple example of a performance matrix, for five projects and five criteria. (Buchanan, 1999).

Table 2.23 Performance Matrix

	F	SD	SC	RM	E
P1	-14	90	0	40	100
P2	129	100	0	0	0
P3	-10	50	0	10	100
P4	44	90	0	5	20
P5	-14	100	0	20	40

Consider the performance data of Table 2.23. For criterion F, the values for Project 1 and Project 3 are -14 and -10 respectively. Does this mean that Project1 is preferred to Project3? Is the small difference of 4 sufficient reasons to make one more preferred than the other? If, for example, a decision maker has to choose between two cups of tea, one with 10 mg of sugar and the other with 11 mg of sugar, could he or she tell the difference? Traditional preference modeling says that because the amount of sugar is not equal, then one will be preferred over the other.

2.3.8.3.3. Thresholds

ELECTRE methods introduce the concept of an indifference threshold, q, and the preference relations are redefined as follows:

a **P** b (a is preferred to b) $g(a) > g(b) + q$ (3.3)

a **I** b (a is indifferent to b) $|g(a) - g(b)| <= q$ (3.4)

While the introduction of this threshold goes some way toward incorporating how a decision maker actually does feel about realistic comparisons, a problem remains. There is a point at which a decision maker changes from indifference to strict preference. Conceptually, there is a good reason to introduce a buffer zone between indifference and strict preference; an intermediary zone where a decision maker hesitates between preference and indifference. This zone of hesitation is referred to as weak preference; it is also a binary relation like **P** and **I** above, and is modelled by introducing a preference threshold, p. Thus we have a double threshold model, with an additional binary relation **Q** which measures weak preference.(Buchanan, 1999). That is:

a**P**b (a is strongly preferred to b)	$g(a)-g(b) > p$	(3.5)
a**Q**b (a is weakly preferred to b)	$q < g(a)- g(b) \leq p$	(3.6)
a**I**b (a is indifferent to b; and b to a)	$\lvert g(a) - g(b) \rvert \leq q$	(3.7)

The choice of thresholds intimately affects whether a particular binary relation holds. While the choice of appropriate thresholds is not easy, in most realistic decision making situations there are good reasons for choosing non-zero values for p and q.

Note that we have only considered the simple case where thresholds p and q are constants, as opposed to being functions of the value of the criteria; that is, the case of variable thresholds. While this simplification of using constant thresholds aids the exposition of the ELECTRE method, it may be worth using variable thresholds especially for the financial criterion where the consideration of larger values may lead to larger indifference and preference thresholds.

2.3.8.3.4. Outranking Relation

Using thresholds, the ELECTRE method seeks to build an outranking relation **S**. To say a **S** b means that “a is at least as good as b” or “a is not worse than b.” Each pair of alternatives a and b is then tested in order to check if the assertion a **S** b is valid or not. This gives rise to one of the following four situations:

aSb and not(bSa); not(aSb) and bSa; aSb and bSa; not(aSb) and not(bSa).

Note that the third situation corresponds to indifference, while the fourth corresponds to incomparability.

The test to accept the assertion aSb is implemented using two principles:

- **A concordance principle** which requires that a majority of criteria, after considering their relative importance, is in favour of the assertion, **the majority principle,** and
- **A non discordance principle** which requires that within the minority of criteria which do not support the assertion, none of them is strongly against the assertion, **the respect of minorities principle.**

The operational implementation of these two principles is now discussed, assuming that all criteria are to be maximized. We first consider the outranking relation defined for each of the criteria; that is,aSjb means that "a is at least as good as b with respect to the jth criterion," j = 1,...,r

The jth criterion is in concordance with the assertion aSb if and only if aSjb. That is, if gj(a) > = gj(b) - qj. Thus, even if gj(a) is less than gj(b) by an amount up to qj, it does not contravene the assertion aSjb and therefore is in concordance.The jth criterion is in discordance with the assertion aSb if and only if b**P**ja. That is, if gj(b) >= gj(a) + pj. That is, if b is strictly preferred to a for criterion j, then it is clearly not in concordance with the assertion that aSb.

Casually speaking, these concepts of concordance and discordance can be thought of as "harmony" and "disharmony." For each criterion j, for every pair of alternatives (a,b) ε A, there is harmony or disharmony with the assertion aSb; that is, a is at least as good as b.It is now possible to measure the strength of the assertion aSb.

1. Concordance Agreement

The first step is to develop a measure of concordance; as contained in the concordance matrix **C**(a,b), for every pair of alternatives (a,b) ε A. Let kj be the importance coefficient or weight for criterion j. We define a valued outranking relation as follows:

$$C(a,b)=1/k \sum_{J=1}^{r} k_j C_j(a,b) \text{ where } k=\sum_{j=1}^{r} k_j \qquad (3.8)$$

$$C_j(a,b) = \begin{cases} 1, & \text{if } g_i(a)+q_i >= g_i(b) \\ 0, & \text{if } g_i(a)+p_I <= g_i(b) \end{cases}$$

$(p_j + g_i(a) - gi(b)) / (p_j - q_j)$, otherwise $j=1,\dots,r$.

Using data from Table 2.24, we calculate the concordance index for the pair of projects P2 and P5.First we define the thresholds and weights ,as in Table3.20.

Table 2.24 Thresholds and weights

	F	SD	SC	RM	E
Indifference Threshold (q)	25	16	0	12	10
Preference Threshold (p)	50	24	1	24	20
Weights	1	1	1	1	1

The concordance calculations for projects P2 and P5 are:

c1(P2,P5) = 1, since 129 + 25 >= -14

c2(P2,P5) = 1, since 100 + 16 >= 100

c3(P2,P5) = 1, since 0 + 0 = 0

c4(P2,P5) = 0.333, since 0 + 12 < 20 and 0 + 24 > 20, then

c5(P2,P5) = 0, since 0 + 30 <= 40.

Therefore **C**(P2,P5) = (1)(1) + (1)(1) + (1)(1) + (1)(0.333) + (1)(0)/(1+1+1+1+1) =0.667

The value of 0.667 measures the strength of the assertion that P2 is at least as good as P5.

Table 2.25 presents the complete concordance matrix.

Table 2.25 Concordance matrix

	P1	P2	P3	P4	P5
P1	1,000	0,800	1,000	0,800	1,000
P2	0,600	1,000	0,800	0,800	0,667
P3	0,600	0,600	1,000	0,600	0,800
P4	0,600	0,800	0,800	1,000	0,750
P5	0,667	0,800	0,800	0,800	1,000

These concordance values are easily interpreted. Since equal weights were used, the concordance value is simply the percentage of criteria where one alternative is at least as good as the other. For example, a value of 0.80 for **C** (P1,P2) means that for four out of five criteria, P1 was at least as good as P2. Only for the financial criterion **F** was P2 strictly preferred to P1; that is, the difference exceeded the preference threshold of 50.

Thus far, no consideration has been given to the discordance principle. In the concordance matrix, we have, in a manner of speaking, a measure of the extent to which we are in harmony with the assertion that a is at least as good as b. But what disconfirming or "disharmonious" evidence do we have? In other words, is there any discordance associated with the assertion aSb? Now let's go on with the discordance.

2. Discordance

To calculate discordance, a further threshold called the veto threshold is defined. The veto threshold, vj, allows for the possibility of a **S** b to be refused totally if, for any one criterion j, gj(b) >gj(a) + vj. (3.9)

The discordance index for each criterion j, dj(a,b) is calculated as:

$$d_j(a,b) = \begin{cases} 0 & \text{if } g_j(a)+p_j >= g_j(b) \\ 1 & \text{if } g_j(a)+v_j <= g_j(b) \quad j=1,....,r. \\ \dfrac{g_j(b)-g_j(a)-p_j}{v_j - p_j} & \text{otherwise} \end{cases}$$

Table 2.26 Veto Thresholds

	F	SD	SC	RM	E
Veto Thresholds	100	60	2	48	90

As shown in Table 2.26, we assume veto thresholds for each criterion.

Consider criterion F, with a veto threshold of 100. We compare projects P1 and P2. It is clear that:

gF(P2) > gF(P1) + vF or 129 > -14 + 100.

Therefore, the discordance index dF(P1,P2) = 1. A discordance matrix is produced for each criterion. Unlike concordance, no aggregation over criteria takes place; one discordant criterion is sufficient to discard outranking.

For each pair of projects (a,b) ε A, there exists a concordance and a discordance measure.

3. Credibility

The final step in the model building phase is to combine these two measures to produce a measure of the degree of outranking; that is, a credibility matrix which assesses the strength of the assertion that "a is at least as good as b." The credibility degree for each pair (a,b) in A is defined as: (3.10)

C(a,b),if

d_j (a,b)<=C(a,b)

S(a,b)= { C(a,b), □ 1-d_j(a,b)/1-C(a,b

Where J (a,b) is the set of criteria such that dj(a,b) > C(a,b).

This formula assumes that if the strength of the concordance exceeds that of the discordance, then the concordance value should not be modified. Otherwise, we are forced to question the assertion that aSb and modify **C**(a,b) according to the above equation. If the discordance is 1.00 for any (a,b) ε A and any criterion j, then we have no confidence that aSb; therefore, S(a,b) = 0.00. The credibility matrix for this simple example is:

Table 2.27 Credibility matrix

	P1	P2	P3	P4	P5
P1	1,000	0,000	1,000	0,800	1,000
P2	0,000	1,000	0,000	0,900	0,667
P3	0,600	0,000	1,000	0,600	0,800
P4	0,214	0,800	0,571	1,000	0,750
P5	0,667	0,000	0,800	0,800	1,000

One notable effect of including discordance has been to decrease the strength of the assertion that other projects are at least as good as Project 2, because of the high value for P2 on criterion F.This concludes the construction of the outranking model

4. Distillation Process

The next step in the ELECTRE III method is to exploit the modeland produce a ranking of projects from the credibility matrix. The general approach for exploitation is to construct two preorders Z1 and Z2 using a descending and ascending distillationprocess (respectively) and then combine these to produce a partial preorder Z = Z1 intersection Z2. The descending distillation process is as follows.

Let $\lambda = \max S(a,b)$. Determine a "credibility value" such that only values of S(a,b) that are sufficiently close to λ are considered; that is, $\lambda - s(\lambda)$. Thus if $\lambda = 1$, let $s(\lambda) = 0.15$. Define the matrix T as: (3.11)

$$T = \begin{cases} 1, & \text{If } S(a,b) > \lambda - s(\lambda) \\ 0, & \text{otherwise.} \end{cases}$$

Further, define the qualification of each project , Q (a) as the number of projects that are outranked by Project a minus the number of projects which outrank Project a. Q (a) is simply the row sum minus the column sum of the matrix T. The set of alternatives having the largestqualification is the first distillate of D1. If D1 contains only one alternative, repeat the previous procedure with A \ D1. Otherwise, apply the same procedure inside D1. If distillate D2 contains only one alternative, the procedure is started in D1 \ D2 (unless the set is empty); otherwise it isapplied within D2, and so on until D1 is used up. The procedure is then repeated starting with A \D1. The outcome is the first preorder Z1; the descending distillation.

The ascending distillation is carried out in a similar fashion except that the projects with the smallest (rather than the largest) qualification are retained first. For this example, the two distillations give the following preorders, as following:

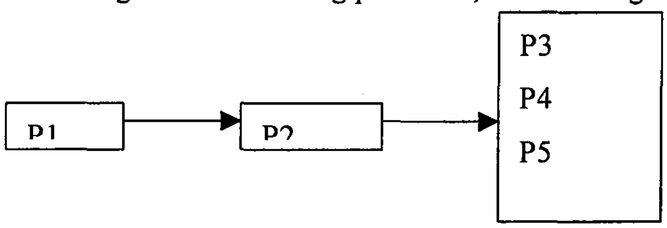

Figure 2.9 Descending distillation

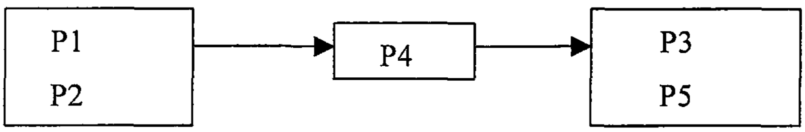

Figure 2.10 Ascending distillation

Projects in the same group are ranked equally; they are at least as good as each other. Based on these two preorders, the final order is shown in Figure 4.

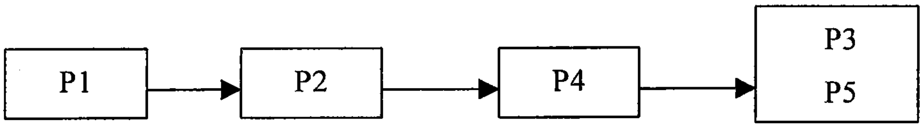

Figure 2.11 Final Preorder

P3 and P5 are ranked together.

2.3.8.3.5. RESULT

A further component of ELECTRE III, as in any good modelling approach is the sensitivity or robustness analysis. Sensitivity of the final rankings to changes in the thresholds and weights, especially, should be undertaken so as to appreciate the robustness of the ranking procedure.

2.3.8.4. PROMETHEE (Preference Ranking Organisation METHod of Enrichment Evaluation)

2.3.8.4.1. Concepts

The PROMETHEE methods are particularly appropriate for multicriteria problems of the following type:

$$\text{Max } \{f1(x), f2(x), \ldots fj(x) \ldots fk(x) \mid x \in A\} \qquad (3.12)$$

where A is a finite set of possible alternatives and $f_j(x)$, j=1,2,....k a set of k evaluation criteria.

A generalized criterion $\{ f_j(a), P_j(a,b) \mid a,b \in A\}$ is associated with each criterion.

Fj(.), j=1,2.....k

For each pair (a,b) in AxA and for each criterion fj(.),the real number Pj(a,b)gives the degree of preference of a over b.For this we consider the deviations.

$$d_j(a,b) = f_j(a) - f_j(b) \qquad (3.13)$$

The preference function is often a function of the difference between two evaluations. (Pandey and Kengpol, 1995)

So we can write :$P_j(a,b) = P_j[f(a)-f(b)] = P_j[d_j(a,b)]$. (3.14)

2.3.8.4.2. Six Possible Types of Generalized Criteria

The PROMETHEE method requires the formulation of generalized criterion for each individual criterion $f_j(.)$ $j=1,2\ldots k$. Six possible generalized criteria can be proposed to decision maker (Fig.3.5). These six criteria can cover most of the needs of real world applications. The effective choice of the criterion to be used is made interactively by the DM and the analyst.

q represents an indifference threshold:The greatest value of d below which there is indifference

p represents a preference threshold:The lowest value of d above which there is strict preference.

2.3.8.4.3. Fuzzy Outranking Graph

$$\Pi(a,b)=\sum_{j=1}^{k} P_j(a,b)W_j \left(\sum_{j=1}^{k} W_j=1\right), \quad (3.15)$$

where $\Pi(a,b)$ expresses how and with what intensity a dominates b for all the criteria according to weight distribution $w_1, w_2 \ldots\ldots w_n$

$\Pi(a,b)$ values obviously enjoy the following properties:

$\Pi(a,a)=0$

$0<=\Pi(a,b)<=1 \ \forall\ a,b \in A$ (3.16)

$\Pi(a,b) \approx 0$ implies a weak global preference of a over b,

$\Pi(a,b) \approx 1$ implies a strong global preference of a over b (Pandey and Kengpol,1995).

2.3.8.4.4. Outranking for Decision Support

For each alternative a ϵ A, the following two outranking dominance flows can be obtained as follows (Vincke, 1989).

$$\Phi^{+}(a) = 1/(n-1) \sum_{B \in A} \Pi(a,b) \text{ (Leaving flow)} \qquad (3.17)$$

$$\Phi^{-}(a) = 1/(n-1) \sum_{B \in A} \Pi(b,a) \text{ (Entering flow)} \qquad (3.18)$$

The positive outranking flow expresses how this alternative is outranking all the others. The higher $\Phi^{+}(a)$, the better the alternative.
The negative outranking flow expresses how this alternative is outranked by all the others. Smaller the value of $\Phi^{-}(a)$, better the alternative (Ülengin et al., 2001).

2.3.8.4.5. The PROMETHEE II Complete Preorder

When the decision maker requires a complete ranking, the net outranking flow is considered as

$$\Phi(a) = \Phi^{+}(a) - \Phi^{-}(a) \qquad (3.19)$$

The higher the net flow, the better the alternative (Pandey and Kengpol, 1995).

The promethee methods may be applied when the following considerations are taken into account:

1. The decision maker can express his preferences between two actions on all the criteria on ratio scales.
2. The decision maker can express the importance he attaches to the criteria on a ratio scale.
3. The decision maker wants to take all criteria into account and is aware of the fact that the weights are representing tradeoffs.
4. For all the criteria the difference between evaluations must be meaningful.
5. None of the possible differences on any of the criteria can give rise to discordance.

6. The decision maker knows exactly what can happen if one or more actions are added or deleted and is fully aware of the influences on the final decision (Keyser and Peeters, 1996).

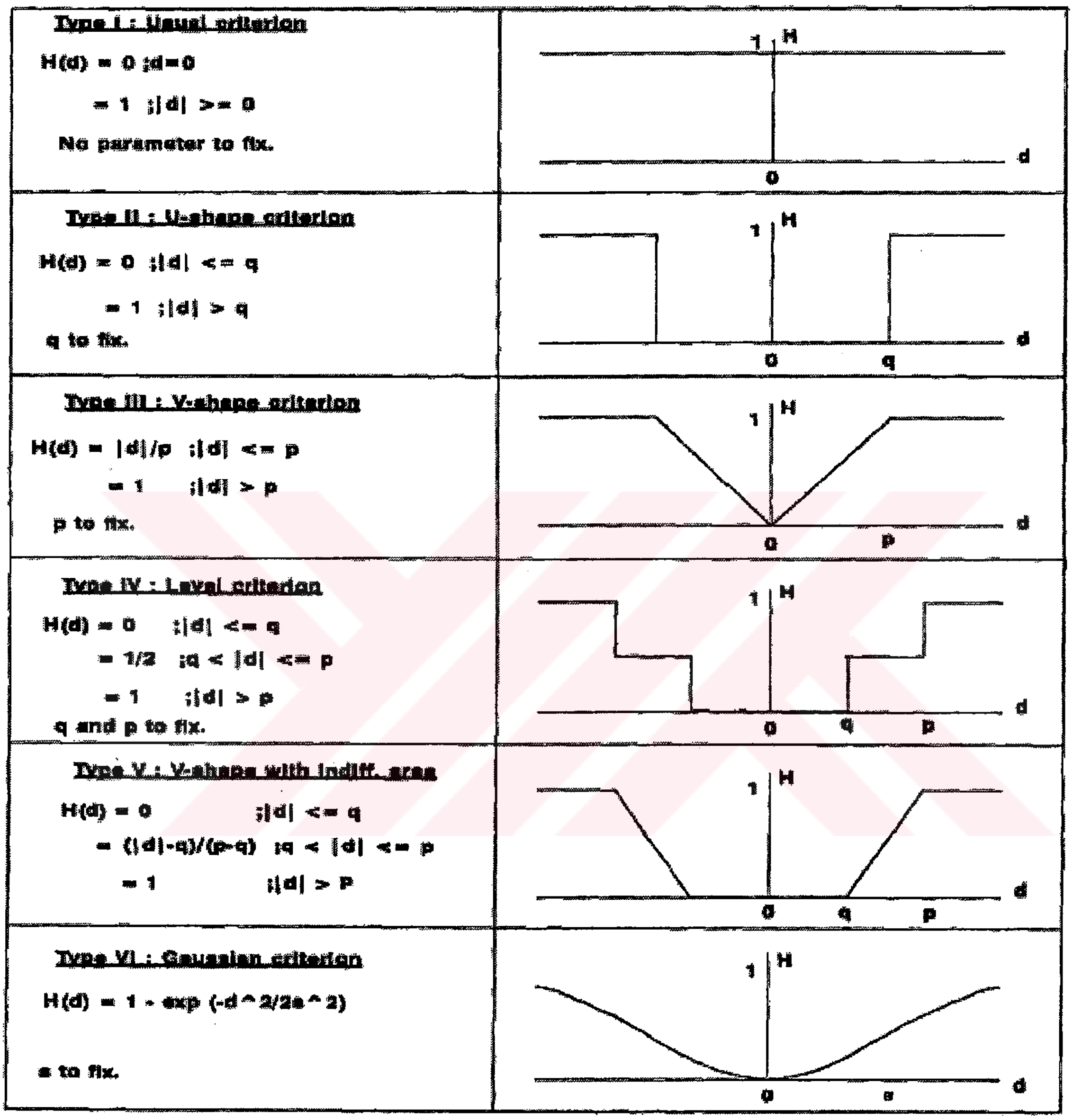

Figure 2.12 Six possible types of generalized criteria used in PROMETHEE. (Pandey and Kengpol, 1995).

2.3.8.4.6. An Application of PROMETHEE

Example: Baseball team evaluation (Olson, 2001).

Criteria:Hitting, power, speed, fielding, pitching

Alternatives: Chicago, Newyork, Pittsburgh, Philadelphia, Brooklyn, Cincinati

Table 2.28 Evaluation Matrix (Olson, 2001).

Weight	**0.31**	**0.1**	**0.09**	**0.19**	**0.31**
	Hitting	**Power**	**Speed**	**Fielding**	**Pitching**
Chicago	0.262	20	283	0.969	1.75
New York	0.255	15	288	0.963	2.49
Pittsburgh	0.261	12	162	0.964	2.21
Philadelph	0.241	12	180	0.956	2.58
Brooklyn	0.236	25	175	0.955	3.13
Cincinati	0.238	16			

Table 2.29 Preference Indices (Olson, 2001).

	Chicago	**New Yor**	**Pittsburgh**	**Philadelphia**	**Brooklyn**	**Cincinati**
Chicago	0	0,91	1	1	0,9	1
New York	0,09	0	0,19	1	0,9	0,9
Pittsburgh	0	0,81	0	0,81	0,81	0,81
Philadelphia	0	0	0,09	0	0,9	0,71
Brooklyn	0,1	0,1	0,19	0,1	0	0,19
Cincinati	0	0,1	0,19	0,29	0,81	0
Sum	0,19	1,92	1,66	3,2	4,32	3,61
Entering	0,038	0,384	0,332	0,64	0,864	0,722

Table 2.30 Netflow Table (Olson, 2001).

Promethee I		Promethee II	
Leaving	Entering	Netflow	
0,962	0,038	0,924	1 st
0,616	0,384	0,232	3 th
0,648	0,332	0,316	2 nd
0,34	0,64	-0,3	4 th
0,136	0,864	-0,728	6 th
0,278	0,722	-0,444	5 th

So we can rank the teams according to Promethee I as following:

Table 2.31 Promethee I Results

Team	Leaving(Max)	Entering (Min)	Rank Order
Chicago	0,962	0,038	1 st
Pittsburgh	0,648	0,332	2 nd
New York	0,616	0.384	3 th
Philadelphia	0,340	0,640	4 th
Cincinati	0,278	0,722	5 th
Brooklyn	0,136	0,864	6 th

Table 2.32 Promethee II Results

Team	Netflow	Rank Order
Chicago	0,924	1 st
Pittsburgh	0,316	2 nd
New York	0,232	3 th
Philadelphia	-0,300	4 th
Cincinati	-0,444	5 th
Brooklyn	-0,728	6 th

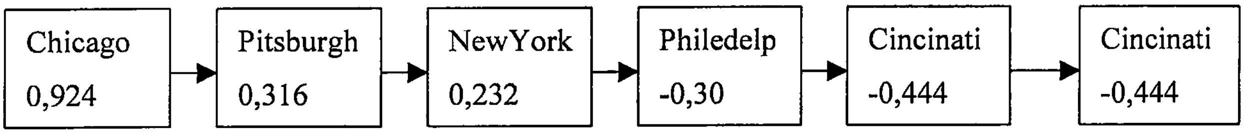

Figure 2.13 Net flow Figure according to Promethee II (Olson, 2001).

2.3.8.4.7. Comparison of PROMETHEE and ELECTRE Methods

The outranking degree of the PROMETHEE method is quite similar to the concordance index in the ELECTRE III method; they are even identical if all functions Fj, are of form 5, except for the fact that the difference and preference thresholds are considered as constant in the PROMETHEE method (which is a simlification but also a restriction, even though one can often go back to it by transforming the criterion). On the other hand, no discordance concept is iintroduced in PROMETHEE (Vincke,1992).

3. AN APPLICATION OF LAPTOP COMPUTER SELECTION BY USING MADM METHODS

In our study, we use AHP, REMBRANDT, ELECTRE III, and PROMETHEE MADM methods for deciding on laptop computer selection.

3.1. DATA

The data utilized to develop the MADM methods were gathered from experts in TOYOTA firm and in Department of Management Information Systems of Boğaziçi University and the journals related to computer.

3.2. ASSUMPTIONS

The purchase of the computer for a firm requires some basic assumptions as listed below: (A list of these is listed as follows)

1.The computers will be only used for the firm's daily routine activities, i.e. there is no need for special software such as Autocad. Microsoft Office software is enough for this purpose.

2.The computers will be connected to a network structure

3.The firm prefers mainly 12 brands of computers, namely, Acer, Apple, Compaq, Dell, Gateway, HewlettPackard, IBM, KDS, Panasonic,Sony, Toshiba, and NEC.

3.3. THE ANALYTIC HIERARCHY PROCESS (AHP)

The Analytic Hierarchy Process (AHP) provides a structure on decision making processes where there is a limited number of choices but each has a number of attributes. The use of AHP has become a popular decision making technique for multiple objective problems. AHP provides a method for identification of objectives, sub-objectives and finally criteria. The simple method of direct comparisons alleviates many of the problems associated from the use of traditional utility theory, allowing the decision maker to structure the various components of the problem into a framework of evaluation. AHP allows for use of both data and judgements. The decision-makers need not interpret the criteria into a numeric framework, AHP allows for the use of both objective and subjective measurements in project evaluation. AHP provides a methodology to asses goals and objectives by decomposing the problem into measurable pieces for evaluation using a hierarchial structure. Designed for problems with multiple attributes, criteria or objectives, decision-makers use this method to prioritizing goals. These goals and objectives are quantified in an understandable structure.

The AHP approach provides a method to systematically structure and organize problems. The decision-maker identifies the interrelationships of the problem based upon how each elements.at the same level. These critical elements are decomposed into progressively more detailed elements, to help define the alternatives at a level that can be evaluated.

The important steps in AHP are as follows:

1. Hierarachy development,
2. Pairwise comparisons,
3. Priority extraction,
4. Model synthesis.

The first step requires the decision maker to decompose the process into hierarchial levels. Decomposition continues to a level that allows the decision-maker to make relative comparisons and evaluations.

The second step requires the decision-maker to asses pairwise comparisons between elements at each level relative to the criteria. These pairwise comparison provides a method to abtain information relative to the decision-makers preferences. The third step uses the evaluation determined at each level to derive relative priorities of the elements. This evaluation is based upon the derived eigenvalues. The final step in AHP is the synthesis of identified priorities from the decision-makers. In this way, alternatives can be assessed as priorities at each level. Using pairwise comparisons, the decision alternatives are assessed at previous levels. Each element, when synthesized, represents an intuitively appealing piece of the problem.

1. Hierarchy Development

The first step of AHP is hierarchy development through the decomposition of the root problem. In the Method represented by this research, the selection of a laptop computer is the primary root. From this root, the model is decomposed into criteria. These criteria are further decomposed into sub-criteria.

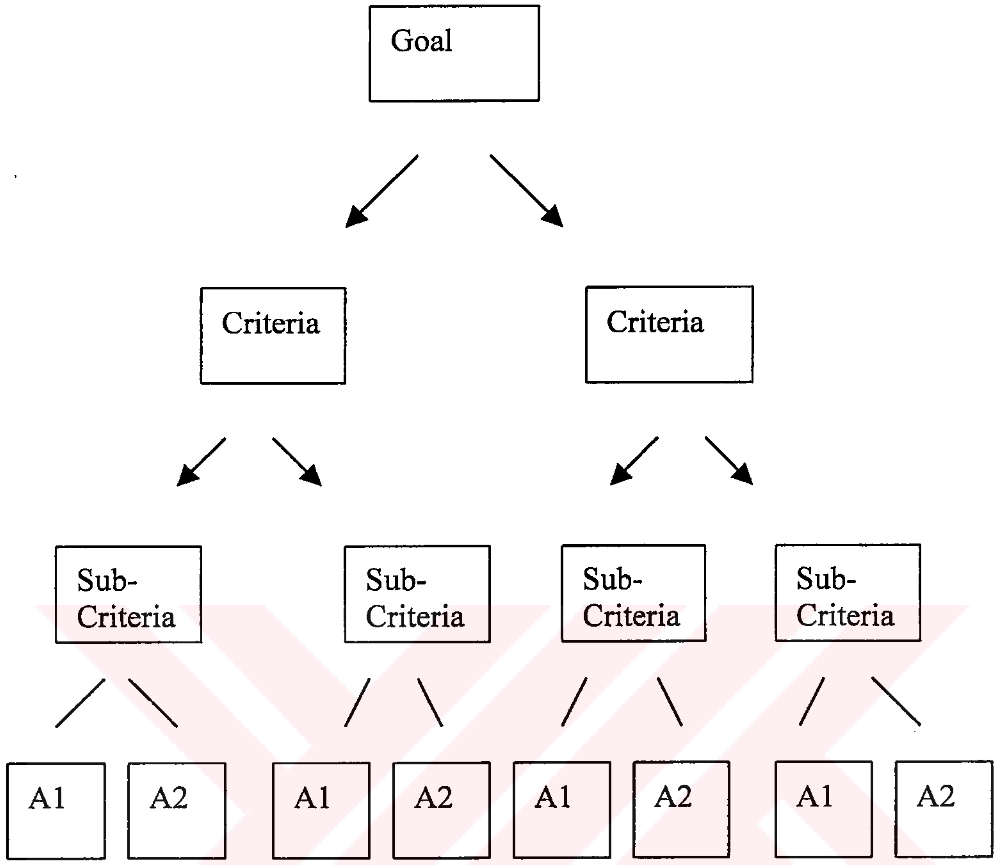

Figure 3.1. Hierarchy Development

2. Pairwise Comparisons

The second step in the AHP process is the pair wise comparison of the elements at each level of the hierarchy. The purpose of the pair wise comparisons is to evaluate the relative preference of each element to the other alternative goals at the same level. These goals are based upon the goals at the preceding level. By comparing each lower level element with the preceding higher level, determination of the value of each lower element relative to the contribution against the immediate higher level is determined. This comparison can be made based upon the importance, preference, likelihood, or absolute value of each criterion. The method of empirical comparison recommended by Saaty is an open scale within the interval (0,10), with 1 assuming the element contributes the same relative contribution to the next highest level element, and 9, assuming that one element contributes the highest possible amount over the other elements. Saaty's scale is shown in Table 3.1.

Table 3.1 AHP Scale

Numeric Scale	Verbal Scale	Explanation
1.0	Equal Important Both Elements	Two elements contribute equally
3.0	Moderate Importance of one element over other	Experience and judgment favor one element over another
5.0	Strong Importance of one element over the other	An element is strongly favored
7.0	Very strong importance of one element over another	An element is very strongly dominant
9.0	Extreme strong importance of one element over another	An element is favored at least an order of magnitude of difference
2.0,4.0,6.0,8.0	Intermediate value in between two adjacent judgments	Used for compromise between two judgments
Increment 0.1	Intermediate value in finer graduation of 0.1 judgments	Used for graduations of judgment

3. Priority Extraction

Once the pairwise comparisons are complete, the resulting values represent the relative weights for each element. Perhaps the most unique aspect of the use of AHP is the allowance for inconsistencies in the human performance of the pairwise comparisons. Because human feelings often do not occur according to well-known statistical properties such as commutative,associative and transistivity.

4. Model Synthesis

The final step in the AHP is the synthesis of this data. The process of synthesis aggregates the weights, such as that element, criterion or alternative will be assigned one value, based upon the synthesis of objectives, criteria, or sub-criteria. This synthesis value can be used for evaluation.

This study explores the use of AHP for deciding on laptop computer purchase.

3.3.1.Problem Definition

The top level goal of this problem is to select the best laptop computer for a firm. There are 6 main criteria (1 st Level) for this problem.

3.3.2. Identification of Objectives, Criteria and Sub-Criteria

The firm's goal is to select the laptop computer which has the best features. The main criteria for achieving this goal are as follows:

1. Brand
2. Cost
3. Computer Performance
4. Warranty Conditions
5. After Sale Service
6. Reliability

It is from these major criteria that all sub-goals will be pegged. Each of these categories encompasses multiple goals or sub-criteria that can be further divided into attributes for final comparisons to evaluate the computers. Figure 3.2 shows the initial hierarchial framework.

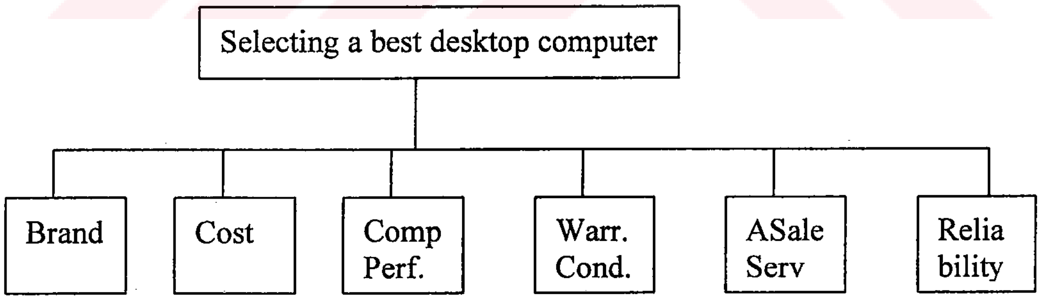

Figure 3.2 Initial Hierarchy Decomposition (1 st Level Decomposition)

Decomposition on the first level is based up on the 6 critera as shown in Figure 3.2.The problem is then decomposed downwardly based upon the sub-objectives.The Brand Criterion is divided into 12 categories which are Acer, Apple, Compaq, Dell, Gateway, Hewlett Packard, IBM, KDS, NEC, Panasonic, Sony, Toshiba as shown in Figure 3.3

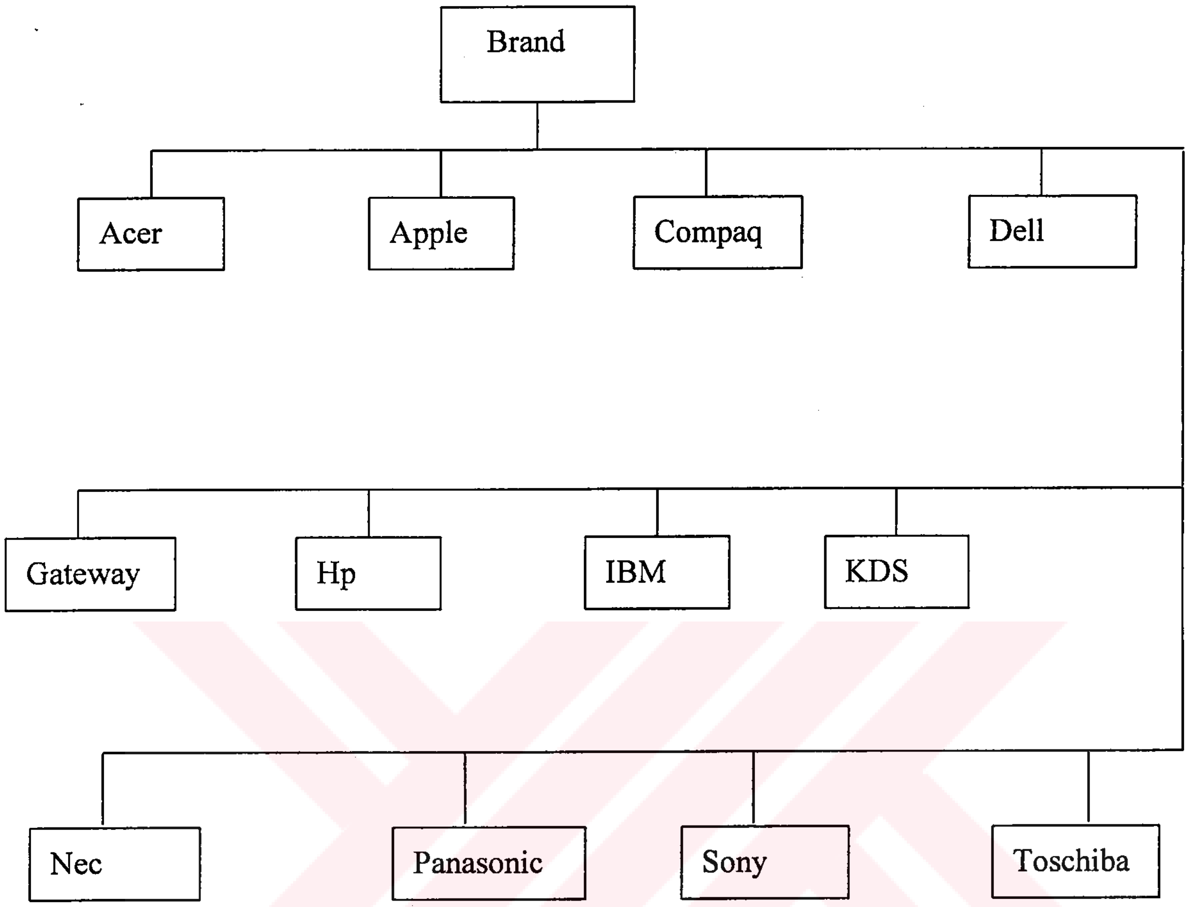

Figure 3.3 Brand Decomposition 2 nd Level)

The Cost Criterion is decomposed into 2 sub-criteria which are Price and Operating Costs as shown in Figure 3.4

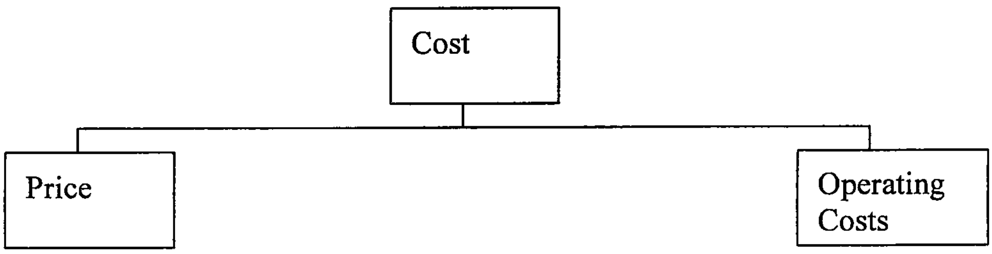

Figure 3.4 Cost Decomposition (2 nd Level)

The Computer Performance Criterion is decomposed into 8 sub-criteria as shown in Figure 3.5.

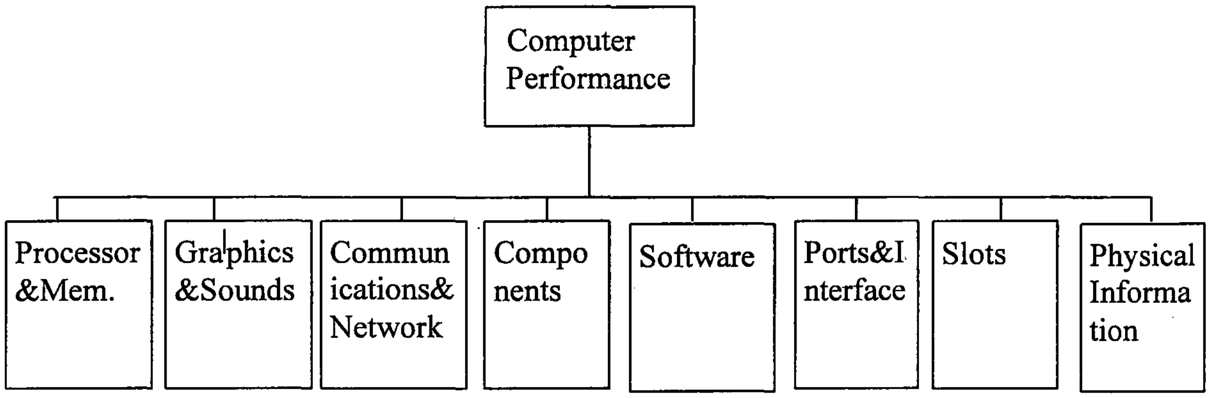

Figure 3.5 Computer Performance Decomposition (2 nd Level)

1. Warranty-Labor
2. Warranty-Parts
3. Warranty-Replacement
4. Support
5. Free Phone Support
6. Detailed Support

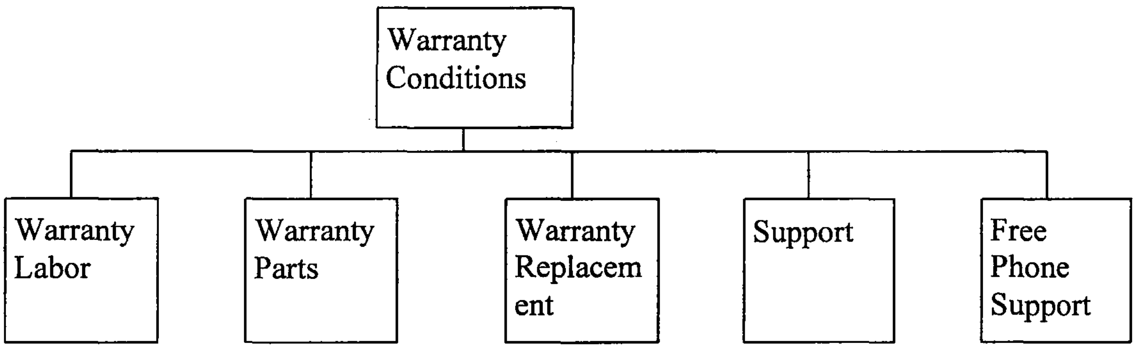

Figure 3.6.Warrranty Conditions Decomposition (2nd Level Criteria)

After Sale Service Criterion are divided into 6 sub-categories as shown in Figure 3.7.

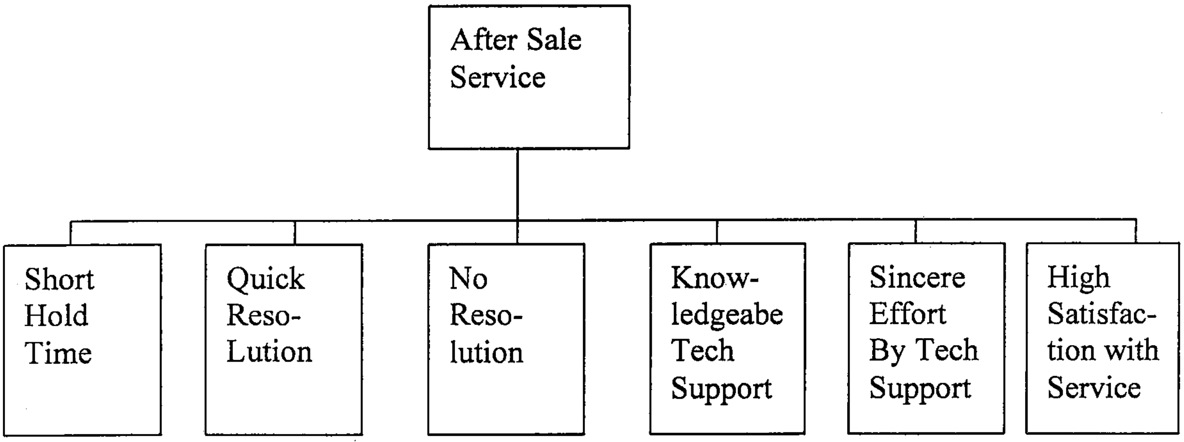

Figure 3.7.After Sale Service Decomposition (2 nd Level)

Reliability (Durability) Criterion are classified into 6 categories as shown in Figure 3.8.

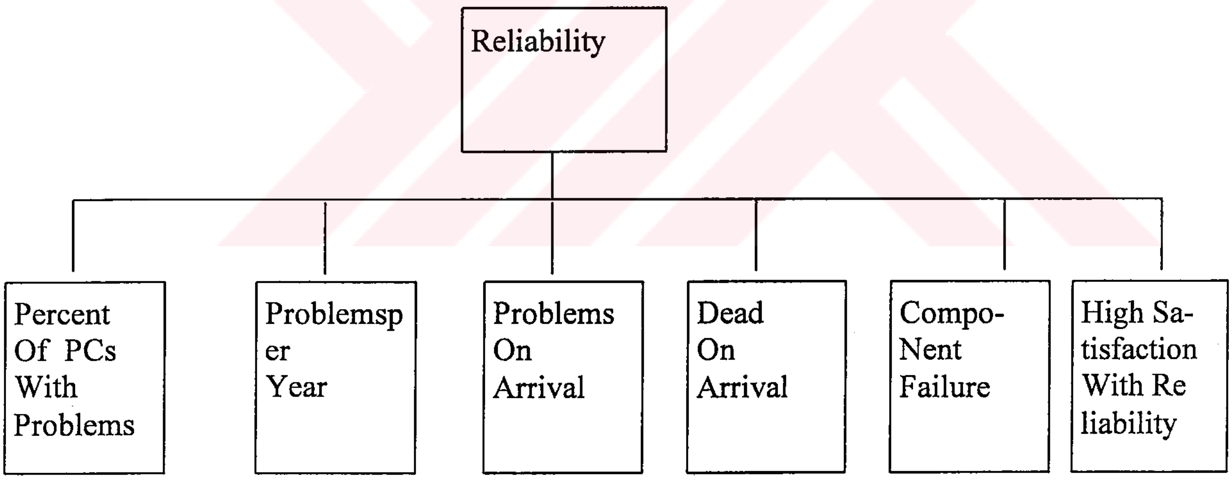

Figure 3.8 Reliability(Durability) Decomposition (2nd Level)

The Computer Performance criterion is divided into 8 sub-categories according to 2 nd level as mentioned in Figure 3.5. These are as following:

1. Processor and Memory
2. Graphics and Sounds
3. Communications and Networking

4. Components

5 Ports and Interfaces

6. Software

7 .Power

8. Physical Information

These criteria are also divided into sub-criteria which are called 3 th level criteria as following

3 th Level Sub-Criteria

Criterion:Processor and Memory

Sub-Criteria

1. Processor Type
2. Processor Speed
3. Installed RAM
4. RAM Type
5. Max RAM
6. Number of RAM Sockets
7. L2 Cache Size
8. Bus Speed
9. Hard Drive Capacity

Criterion:Graphics and Sounds

Sub-criteria

1. Video RAM
2. Display Mode
3. Graphics Card
4. Graphics Interface
5. Sound Support
6. Screen Size
7. Screen Technology

Criterion:Communications and Networking

Sub-criteria

1. Network Ready
2. Network Support
3. Modem Type
4. Modem Speed
5. Wireless Capability
6. Wireless Technology
7. Security Options
8. Security Features

Criterion:Components

Sub-criteria

1. Included Drivers
2. Integrated Floopy
3. CD Rom Read Speed
4. DVD Rom Read Speed
5. Speakers
6. Port Replicator/Docking Station
7. Camera
8. Keyboard

Criterion:Software

Sub criteria

1. Operating System
2. Office Software
3. Other Software
4. Software Bundle

Criterion:Ports and Interfaces

Sub-criteria

1. Network Connectors
2. Video Ports
3. USB
4. SCSI
5. Parallel
6. Serial
7. PS/2 (Mouse/Keyboard)
8. Audio Connectors
9. Zoomed Video Port
10. Infrared Connector

Criterion:Power

Sub-criteria

1. Battery Type
2. Battery Cells
3. Battery Life
4. Longer Battery Options

Criterion:Physical Information

Sub-criteria

1. Depth
2. Height
3. Width
4. Weight
5. Pointing Device
6. Form factor

7. Configurable

3.3.3. Definition and Explanation of Criteria and sub-criteria

In our application the main criteria (1 st level) are brand, cost, computer performance, warranty conditions, after sale service, reliability. Now let's begin the explanation of these criteria with brand.

3.3.3.1. Brand

Brand is usually the name of the company that makes the particular notebook, although sometimes companies will produce several brands. In our application the brands are: Acer, Apple, Compaq, Dell, Gateway, HewlettPackard, IBM, KDS, NEC, Panasonic, Sony, Toshiba.

3.3.3.2. Cost

In our model cost is composed of two patrs which are price and operating costs

Price: We list the Average Street Price (ASP). Although ASP may be higher than the best retail price you can find it is a good indication of what you may pay at a typical retailer. When an ASP is not available we list the Manufacturer Suggested Retail Price (MSRP).

Operating Cost: Operating cost is the cost for operating and maintaining for a laptop computer.

3.3.3.3. Computer Performance

Computer performance is composed of the following sub-criteria,

1. Processor and Memory
2. Graphics and Sounds
3. Communications and Networking
4. Components
5. Ports and Interfaces
6. Software
7. Power
8. Physical Information

These criteria are also divided into sub-criteria as following. Now, let's begin with the Processor and Memory Criteria. Processor and Memory criteria are also composed of the following sub-critera which is known as 3 th level criteria.

1. Processor Type
2. Processor Speed
3. Installed RAM
4. RAM Type
5. Max RAM
6. Number of RAM Sockets
7. L2 Cache Size
8. Bus Speed
9. Hard Drive Capacity

1.Processor and Memory

Processor Type: The processor (also known as the CPU, Central Processing Unit) is the circuitry that processes and acts on the instructions that software programs send to the computer. The type of processor in the notebook plays a part in determining the speed of the system, and how well it handles graphics and multi-tasking. The mix of processors can be quite bewildering. Here's a quick introduction to the various classes of processors:

- **AMD Athlon:** This is the newest and fastest AMD processor around. Its very fast and handles complicated graphics smoothly.
- **AMD Duron:** Designed for everyday home and office use, the AMD Duron provides the budget conscious shopper with quick speed and 3DNow technology for improved graphics performance.
- **AMD K6 2:** The newer version of the K6 adds 3DNow technology, which accelerates 3D performance with graphics and gaming applications. It also comes with high processor speeds.
- **AMD K6 III:** The most advanced version of the K6 processor, the K6 III has all the benefits of the K6 2 but integrates the secondary cache into the processor core. This means the processor runs even faster.
- **Intel Celeron:** The budget conscious version of the Pentium II, this processor is inexpensive, very speedy and efficient.

- **Intel Pentium II:** This high-quality processor is great with multimedia applications, has a large cache, and is very speedy.
- **Intel Pentium III:** This is the third generation Pentium chip. One key improvement over earlier versions is in its handling of sound and graphics.
- **PowerPC G3/750:** A processor used in Apple products, this is found in iMacs, G3s, and PowerPCs. It has great speed and a good sized cache, at a relatively affordable price.
- **PowerPC G4:** A processor used in Apple products, the G4 has some serious speed, and shines when put to work on graphics and video data.
- **Transmeta Crusoe:** A recent addition to the processor market, the Crusoe is a hardware-software hybrid, designed to provide a lighter, cooler, and less power-consuming processor for your notebook.

Processor Speed: The processor speed is the rate at which the central processing unit performs calculations. It is measured in megahertz, (MHz) or gigahertz, (GHz). 1000 MHz equals 1 GHz.

Installed RAM: (RAM) Random Access Memory holds all running programs, applications and open files so that they can be accessed and modified by the computer's central processing unit (CPU). If you plan to use a lot of multimedia or graphics intensive programs on your notebook, you'll need to make sure you're getting enough RAM. In addition to the amount of installed RAM you might also want to check the number for the maximum RAM and the number of RAM sockets.

RAM Type: There are 4 types of RAM to be aware of: DRAM, EDO (Extended Data Out), SDRAM, and FPM (Fast Page Mode). DRAM (D is for Dynamic) is the most common type, and works fairly quickly. EDO RAM works faster than DRAM when paired with a faster processor. SDRAM (S is for Synchronous) synchronizes the DRAM with optimal clock speek of the processor, increasing the speed of the memory access. Last there is FPM RAM, which is a type of DRAM that can access RAM quickly and reduce the amount of power used.

Max RAM: This is the amount of installed RAM, plus the amount of RAM that can be added.

Number of RAM Sockets: The number of RAM sockets is an indicator of how much space is available to expand the computer's memory. The sockets are generally of the type called "DIMM" and more sockets provide greater flexibility in upgrading the notebook's memory.

L2 Cache Size: The cache is a temporary storage place in the computer's processor. This is where the computer looks first for information, before searching the entire memory. A cache improves the speed of the computer, as areas of programs that the notebook uses frequently are stored here for faster access. There are two types of cache, the primary cache which is stored directly on the processor chip and can be accessed at full speed (typically a smaller cache), and the secondary cache which is outside the processor and can be accessed at half speed (the larger cache).

Bus Speed: The bus is a path that connects all the devices and drives of the computer with the processor. It picks up and drops off signals. The faster the bus speed, the quicker the computer will be at processing signals.

Hard Drive Capacity: The hard drive is where permanent data is stored--applications, documents, all your permanent information. Although disks may be used to store info, they are backups, with the hard drive as the primary storage area. Storage on a hard disk is different from RAM, which loses its memory when the computer is shut off, and starts anew the next time the computer starts. Computers these days come with very large hard drives, with the capacity measured in gigabytes. Notebook hard drives can range from under one gigabyte to over 30 gigabytes.

2. Graphics and Sounds

Graphics and Sounds are composed of the following sub-criteria

1. Video RAM
2. Display Mode
3. Graphics Card
4. Graphics Interface
5. Sound Support
6. Screen Size
7. Screen Technology

Video RAM: Measured in Megabytes, video memory (or VRAM) is a type of RAM that stores the image data. It serves as the connection between the standard RAM and the display, and helps speed up the process of displaying images. A large video memory comes in particularly handy if you like to play graphics intensive video games.

Display Mode: Notebook displays have a range of display modes, which are fixed resolutions. Resolution measures the sharpness of the picture on the display. It's measured in pixels, giving the number of horizontal pixels times the number of vertical pixels. As the display resolution increases, the picture gets sharper. The display modes included are the following:

- **SVGA:** 800 x 600 pixels.
- **XGA:** 1024 x 768 pixels.
- **SXGA:** 1280 x 1024 pixels.
- **SXGA:** 1400 x 1050 pixels.
- **UXGA:** 1600 x 1200 pixels.

Graphics Card and Interface: Some graphics run using the standard PCI interface, which is pretty good, but not created specifically to speed up graphics. On the other hand, the AGP interface enables 3D graphics to be shown fast and smoothly. It comes at different speeds, making the presentation even more fluid.

Sound Support: The type of sound technology that is supported by the computer

Screen Size: The size of the screen can make a huge difference on the eyes, and on the viewing area. The larger the screen, the easier it is on the eyes. However, the tradeoff is the increase in weight as the screen size grows, as well as the higher price tag. Screen size is measured diagonally.

Screen Technology: The display of the notebook is often the most expensive part of the machine. All displays are LCDs (Liquid Crystal Displays), which are much thinner than the CRTs (Cathode Ray Tubes) used in traditional desktop monitors. In addition to looking at display size, it's worth looking at the type of LCD used, as they do differ in quality. The passive matrix LCD is the most basic type of display, giving a good picture at a lower price. Two common types of passive matrix LCDs are DSTN and HPA (High Performance Addressing). HPA tends to be a bit sharper than dual-scan, and gives a wide viewing angle. The active matrix LCD improves on passive matrix technology and gives a smoother, more responsive image with a wider viewing angle. This wide viewing angle helps prevent the screen washout that can occur with other monitors when looked at from the side. The most common active matrix display is called TFT (Thin-Film Transistor).

3. Communications and Networking

Communications and Networking are composed of the following sub-criteria

1. Network Ready
2. Network Support
3. Modem Type
4. Modem Speed
5. Internet Service Provided
6. Wireless Capability
7. Wireless Technology

Network Ready: Indicates that the notebook is configured to interface with a network.

Network Support: There are different kinds of ethernet LANs (Local Area Networks), and here we list which the notebook can support.

Modem Type: A modem uses a phone line to connect to the Internet. Not all computers are equipped with a modem. Of those that are, the V.90 modem is most common. Some modems are integrated into the notebook, which makes them difficult to upgrade, whereas modular or card modems are removable, which makes them easy to upgrade or to replace with another needed component.

Modem Speed: The rate at which the modem can transfer information to your computer. A higher speed means a faster connection.

Internet Service Provided: If the manufacturer provides any kind of internet service, it is indicated here.

Wireless Capability: Notebooks are now on the market that use new technologies that connect computers to other devices without wires. The two technologies are Bluetooth and IEEE 802.11b. Bluetooth is a very new technology and will be used primarily for short distance wireless connections. 802.11b operates over longer distances and is used more in business environments. These technologies serve different functions, and some models are configured to work with both.

Wireless Technology: Here we indicate which type (or types) of wireless technology—Bluetooth and/or 802.11b -- is used with the notebook.

4.Components

1. Included Drivers
2. Integrated Floopy
3. CD Rom Read Speed
4. DVD Rom Read Speed

5. Speakers
6. Port Replicator/Docking Station
7. Camera
8. Keyboard

Included Drivers: There are six types of drives (a place for storing information) that are available with notebooks (aside from the hard drive):

- **Floppy Drive:** The floppy drive is the most commonly found drive on notebooks, and lets you transfer files easily with floppy disks (which hold 1.44 MB). Although there are some notebooks that don't have them, most do.
- **CD-ROM Drive:** For running programs and playing games, a CD-ROM drive is very important. Most software programs use CD-ROMs for installation. CD-ROMs can hold up to 650 MB.
- **CD-R(W):** The CD-R drive can write information to a CD-ROM, which has a great deal more space than the standard floppy. The CD-RW takes CD-Rs a step further, not only can information be stored on the CD, but it can be written to the CD. RW stands for rewritable, which means that existing information can be overwritten with new information.
- **DVD-ROM Drive:** A step up from the CD-ROM drive is the DVD-ROM drive, which in addition to accomodating CD-ROMs and audio CDs, can play DVDs, which have a much greater storage capacity (20 times more)and can play movies as well.
- **Imation LS-120 SuperDisk:** This is like a zip drive (a drive that uses disks which store much larger amounts of information than the standard floppy). The difference is that the Imation accepts standard size floppy disks (1.44 MB) as well as Imation disks (120 MB) for storing information.
- **Iomega Zip:** The zip drive can access zip disks, the high capacity storage medium which is the equivalent of almost 70 floppy disks. If you need to transfer really large files, a zip disk is a lifesaver.

- **MultiBay: MultiBay** devices allow for hot-swapping of hard drives, floppy drives, and CD-ROM, CD-RW, and DVD-ROM drives. The term "hot Swappable" indicates that a drive can be removed or replaced without turning off the system and rebooting.

Integrated Floopy: Some floppy drives are integrated into the notebook, meaning that they are not removable (this is also called built-in or internal floppy). Others are modular, and can be removed and replaced with another component, or left empty to save weight.

CD-ROM Read Speed : The speed at which the CD-ROM drive reads CD-ROMs, expressed as a multiple of x (1x, 2x, …), where x equals a transfer rate of 150kbs.

DVD-ROM Read Speed : The speed at which the DVD-ROM drive reads DVDs. Expressed as a multiple of x.

Speakers : The type of the speaker system of a laptop.

Port Replicator/Docking Station: With a docking station, instead of plugging all the peripherals directly into the notebook, the notebook plugs into the docking station, which has all the peripherals attached. It also has slots for expansion boards and storage devices. This makes it easy to detach and transport the notebook. The port replicator uses a single plug to connect the notebook to peripherals. Some notebooks have both a port replicator and a docking station.

Camera: A new trend in notebooks some now are available with an integrated camera which can take still pictures (and sometimes motion too).

Keyboard: The keyboard type of a laptop.

5. Ports and Interfaces:

1. Network Connectors
2. Video Ports
3. USB
4. SCSI
5. Parallel
6. Serial
7. PS/2(Mouse/Keyboard)
8. Audio Connectors

9. Zoomed Video Port

10. Infrared Connector

Network Connectors: Network connectors (also called Registered Jacks-RJ)are types of telephone connectors, which are the interface between your computer and networks (including the internet). The two most important types are the RJ-11 found on almost all laptops, this is the standard telephone connection, and the RJ45 Twisted Pair, which allows connection to ethernet systems.

Video Ports: There are a number of different kinds of video ports that can come with a notebook. Standard on just about all of them is the monitor port, which allows the notebook to be connected to an external monitor. In addition, there are NTSC or NTSC/PAL ports, which can connect to television signals. The S-Video port is great for TV connections, as well as the component port. The IEEE-1394 port is used to transfer digital video to the notebook.

USB: The USB interface is a godsend for those people who are tired of all the steps that they have to go through to plug in a new device. USB is plug and play, the computer doesn't even have to be turned off. It is the new standard interface, replacing parallel ports.

SCSI: The SCSI is a very flexible and fast interface allowing the computer to communicate with components quickly and efficiently. Usually it is installed with an adapter card, but there are some notebooks which come with the interface already installed.

Parallel: The parallel port is the original standard interface (now being replaced by USB), which is needed to plug in peripherals such as printers and scanners.

Serial: Serial interfaces are probably the slowest of all the interfaces, used for devices that don't require a lot of information to be transferred.

PS/2: The PS/2 interface allows you to plug in such peripherals as a mouse or keyboard.

Audio Connectors: Connectors used for attaching audio equipment or transferring audio information. There are a few different audio connectors that will come with a computer, all performing various sound functions. Options include lines in and out, as well as microphone input and MIDI. Some also have a digital output, which allows for the transfer of digital information to another system (such as an audio receiver).

Zoomed Video Port: This port makes it possible for the notebook to have full screen video and fancy graphics without having it be a drain on the battery or processor.

Infrared Connector: Many computers come with an infrared connector, which can communicate with compatible devices without having to connect through cables and wires.

6. Software

Subcriteria

1.Operating System

Operating System: The type of operating system the product comes with or can work with. The operating system may be the Macintosh OS, one of the many different versions of Microsoft's Windows, or Linux.

7. Power

Sub-criteria

1.Battery Type

2.Battery Cells

3.Battery Life

4.Longer Battery Options

Battery Type: There are two types of batteries to look for with notebooks-Nickel Metal Hydride (NiMH)and Lithium Ion (Li-Ion). Although NiMH is a long lasting stable battery, Lithium Ion lasts longer and often offers extended length or dual battery options.

Battery Cells: The number of cells contained in the battery. More cells generally mean a longer lasting battery.

Battery Life: For anyone dependent on using their notebook while on the road, battery life is crucial. Unfortunately, battery life is not the easiest number to determine. There is no standard, and the life will vary according to what the computer is used for and it's capabilities for powering down systems not in use. This number is that given by the manufacturer, but keep in mind that your own results at home may vary.

Longer Battery Options: Some notebook models come with options for extending the operating time between rechargings of the battery. Alternatives include providing a space for storage of a second battery, providing second or third batteries, or providing a battery with 2-4 times the nurmal life. Most often, these options need to be purchased separately.

8. Physical Information

Sub-criteria

1. Depth
2. Height
3. Width
4. Weight
5. Pointing Device
6. PC Card Slots

Depth : The depth of the notebook, measured in inches.

Height : The height of the notebook, measured in inches.

Weight : Weight is an important consideration when looking at notebooks. Remember that the more bells and whistles, the heftier the notebook will get. If a desktop replacement is what's needed, be prepared to look at heavier notebooks. However, if a less robust system will do, then the frequent traveler will be thankful for saving a few pounds and getting a lighter system.

Width : The width of the notebook, measured in inches.

PC Card Slots : A PC Card is about the size of a credit card, and fits into the notebook. It can be used to expand memory, add on a new component or hard drive, add a sound card, etc. There are 3 types of cards, varying in terms of thickness. Type I is the thinnest and typically is used for memory. Next in scale, type two slots can be used for modem, SCSI, and sound cards. The thickest is the type III card, which is used for big components such as hard drives. Larger slots can accommodate the smaller sized cards.

Pointing Device/Stick: About the size of an eraser, the pointing stick sits in the middle of the keyboard. Pushing the stick in the desired direction moves the cursor around the screen.

3.3.3.4. Warranty Conditions

Warranty Conditions are composed of the following sub-criteria:

1. Warranty-Labor
2. Warranty-Parts
3. Warranty-Replacement

4. Support
5. Free Phone Support

Warranty-Labor : Period of coverage for repair costs associated with fixing problems.

Warranty-Parts : Period of coverage for replacing faulty or damaged parts.

Warranty-Replacement : Period of coverage for replacing a damaged or faulty system that cannot otherwise be repaired.

Support: There are a number of different types of support options that manufacturers offer to their notebook users. They can provide support through their web site, over the phone, remote/backup recovery, damage replacement, premium support (for those who want further support beyond the standard package), and technical support for software as well as hardware.

Free Phone Support: Although your computer can break down at any time, many manufacturers will only give free help over the phone for a limited period. After that, often users have to call a toll number, paying to get support for their technical difficulties.

Detailed Support: Further details about the support offered from the manufacturer.

3.3.3.5. After Sale Service Criteria

After Sale Service criteria is composed of the following sub-criteria.

1. Short hold time
2. Quick resolution
3. No resolution
4. Knowledgeable tech.support
5. Sincere effort by tech. Support
6. High satisfaction with service

Short Hold Time: When a laptop has a problem it is desirable that it must be provided support by the manufacturer in a short time.

Quick Resolution: In case of a problem, it must be solved in a quick response.

No Resolution: If it is provided no support, and the problem exists, that is called no resolution.

Knowledgeable Technical Support and Sincere Effort by Technical Support: There are a number of different types of support options that manufacturers offer to their laptop users. They can provide support through their web site, over the phone, remote/backup recovery, damage replacement, premium support (for those who want further support beyond the standard package), and technical support for software as well as hardware.

High Satisfaction with Service: It expresses the satisfaction of the laptop owner's.

3.3.3.6. Reliability Criteria

Reliability criteria is composed of the following sub-criteria

1. Percent of PCs with problems
2. Problems per year
3. Problems on arrival
4. Dead on arrival
5. Component failure
6. High satisfaction with reliability

Percent of PCs with problems: The number of PCs with problems in terms of percentage.

Problems per Year: The number of the problems in a year. Here the problem is important. For example a laptop has a lot of problems in a year.

Problems on Arrival: This expresses a laptop has a problem when it was bought from the manufacturer.

Dead on Arrival: This expresses a laptop is completely out of order when it was first bought from the manufacturer.

Component Failure: A component of a laptop is completely out of order.

3.3.4. Alternatives

In our application , there are mainly 12 brands of computers.These are as follows:

1. Acer
2. Apple
3. Compaq
4. Dell
5. Gateway
6. Hewlett Packard
7. IBM
8. KDS
9. NEC
10. Panasonic

11. Sony

12. Toshiba.

The alternatives are derived from these brands.So we can write the alternatives as follows:

1. Acer Model 1, Acer Model 2, Acer Model 3,.........Acer Model N,

2. Apple Model1, Apple Model2,...............................Apple Model N,

3. Compaq Model 1, Compaq Model 2,.....................Compaq Model N,

4. Dell Model 1, Dell Model 2,..................................Dell Model N,

5. Gateway Model 1, Gateway Model 2, ...Gateway Model N,

6. Hp Model 1, Hp Model 2,.......................................Hp Model N,

7. IBM Model 1, IBM Model 2..................................IBM Model N,

8. KDS Model 1, KDS Model 2.................................KDS Model N,

9. NEC Model 1, Nec Model 2,..................................NEC Model N,

10. Panasonic Model 1,...Panasonic Model N,

11. Sony Model1,Sony Model 2.................................Sony Model N,

12. Toschiba Model 1,...Toschiba Model N.

3.3.5. Conversions and The Calculations of The Weights of The Criteria and Sub-Criteria

It is difficult to decide on laptop computer selection because of the criteria.Because people in the decision process decide according to some varying criteria. Some of these criteria may have higher priorities than the other ones. But the data which can be used in computing the priority of the criteria can be qualitative or quantative. So the qualitative data must be converted to the numerical scale. For example one of the features of the laptop computer is Integrated Floopy. It can be yes or no.So we have to convert it to a numrical scale.So we can say that Yes =1 and No = 0.

We begin to analyze the data of the laptop computers from the main criteria (first level).

Main Criteria are:Brand, Cost, Computer Performance, Warranty Conditions, After Sale Service,Reliability.

In order to calculate the weights of the main criteria first of all a questionnaire is applied. The questionnaire is shown in Appendix A. By using the Saaty's scale all the paticipants fill the questionnaire and then using the Excel sheet the weights of the criteria are calculated. The procedure can be explaned as follows:

For example, person A filled out the questionnaire related to the main criteria as follows.

Table 3.2 Calculation of weight for main criteria in Laptop computer case

	Cost	Computer Performance	Brand	Warranty Conditions	After Sale Service	Reliability
Cost	1	1	3	1/3	1/3	1/5
Computer Performance	1	1	5	3	1	1/5
Brand	0,33333	0,2	1	1/5	1/3	1/7
Warranty Conditions	3	0,33333	5	1	1	1/3
After Sale Service	3	1	3	1	1	1/3
Reliability	5	5	7	3	3	1
	13,33	8,53	24,00	8,53	6,67	2,21

Table 3.3 Table of normalization process

Cost	0,075	0,117	0,125	0,039	0,050	0,091
Computer Performance	0,075	0,117	0,208	0,352	0,150	0,091
Brand	0,025	0,023	0,042	0,023	0,050	0,065
Warranty Conditions	0,225	0,039	0,208	0,117	0,150	0,151
After Sale Service	0,225	0,117	0,125	0,117	0,150	0,151
Reliability	0,375	0,586	0,292	0,352	0,450	0,453
	1,000	1,000	1,000	1,000	1,000	1,000

Table 3.4 Table of results for main criteria

Criteria	Priority Vector	Weighted Sum	Lambda
Cost	0,083	0,545	0,577
Computer Perf.	0,165	1,115	6,738
Brand	0,038	0,237	6,238
Warranty Conditions	0,148	0,929	6,259
After Sale Service	0,148	0,963	6,528
Reliability	0,418	2,813	6,733

$$CI = \frac{\lambda\ max - n}{n - 1} \quad 0,102$$

RI = 1,24

λ max 6,512

CR= CI / RI = 0.083 < 0.10 CR is acceptable.

Finally, person A's weights are found as above.Here the weights of the main criteria for person A are as follows:

Table 3.5 Table of weights for the main criteria

Criteria	**Weights**
Cost	**0,083**
Computer Performance	**0,165**
Brand	**0,038**
Warranty Conditions	**0,148**
After Sale Service	**0,148**
Reliability	**0,418**

Aggregation:

This procedure was repeated for all participants and then by taking average of all the persons, the weights were calculated.

3.3.5.1. Brand

In a pair wise comparison we can calculate the weights of the brand criteria by using Saaty's scale.

3.3.5.2. Cost

We use the price of the computers and calculate the eigenvectors or priority vectors of the computers according to criteria cost.

Table 3.6. The calculation of weights of brands according to price

Brand	Price	Eigenvector
1.Sony VAIO PCG-F430	1349.00	**0.11**
2.KDS Valiant6480iPTD-01	1399.96	**0.12**
3.AppleiBook M7721LL/A	1359.00	**0.11**
4.Gateway Solo5300cs	1399.00	**0.12**
5.Compaq Presario12XL310	1399.9	**0.12**
6.IBM ThinkPad i Series 1300	1299.00	**0.11**
7.Acer TravelMate 210	929.00	**0.08**
8.Dell Inspiron4000	1299.00	**0.11**
9.Hp Omni Book	1399.0	**0.12**

3.3.5.3. Computer Performance

In order to calculate the weights of the subcriteria of the computer performance first of all Computer Performance Questionnaire is applied. By using the Saaty's scale the weights of the criteria are calculated.

1.Processor and Memory

Processor Type:.We collect these values from the experts.In the conversion we use the following values.

Table 3.7. Comparison of Processor Types (www.pcworld.com)

Brand	Processor Speed	Average
Intel Pentium 4	2000/100	**3.345**
AMD Athlon	1400/133	**3.121**
Intel Celeron (Tualatin)	1200/100	**2.602**
Intel Pentium III (Tualatin)	1133/133	**2.474**
AMD Duron	1100/100	**2.438**
Intel Celeron (Cu-Mine)	1100/100	**2.366**
AMD Duron	1000/100	**2.244**
Intel Pentium III (Cu-Mine)	1000/133	**2.176**

Processor Speed: We can calculate the weight of the processor speed of each laptop computer by dividing the value by the total.

Installed RAM: We can calculate the weight of the Installed RAM of each laptop computer by dividing the value by the total.

RAM Type: By collecting values from the experts,we assign a number to each type and later we calculate the weights.

Max RAM: We can calculate the weight of the Max RAM of each laptop computer by dividing the value by the total.

Number of RAM Sockets: We can calculate the weight of the Number of RAM sockets of each laptop computer by dividing the value by the total.

L2 Cache Size: We can calculate the weight of the L2 Cache size of each laptop computer by dividing the value by the total.

Bus Speed: We can calculate the weight of the bus speed of each laptop computer by dividing the value by the total.

Hard Drive Capacity: We can calculate the weight of the hard drive capacity of each laptop computer by dividing the value by the total.

2.Graphics and Sound:

Video RAM: We use normal Video RAM values.

Display Mode: We use display mode values, for example if the display mode of Pentium III is 1024X768,we multiply these values and later we compare this value with the other ones.

Graphics Card and Interface: By collecting values from the experts we assign each type a value and then later, we compare.

Screen Size: We use each computer's values.

3. Communications and Networking:

Here, we use the values of each sub-criteria. But some criteria such as wireless capability have some values like yes or no.In this case we assign 1 for yes and 0 for no.

4. Components: In the components of Included drivers,CD Rom speed,DVD Rom Speed we use their own values ,but we use 0 and 1 instead of yes or no for speakers,camera etc.

5. Ports And Interfaces

In this component there are values such as yes or no and type values and the expert's values.We use these values as mentioned above.

6. Software: By gathering values from the experts we assign each type of software a number , and calculate the priority vectors.

7. Power: We use their values while making a calculation for priority.

8. Physical Information: We use these measures as the basis for comparisons.

3.3.5.4. Warranty Conditions

Here we use the values of each attribute, but we must be careful about the units. For example if we consider warranty replacement attribute, its all computer models' units must be the same i.e.all must be day,month or year.

3.3.5.5. After Sale Service

We gathered some information from the experts and the computer journals (pcworld.com). They graded each element of the criteria as not applicable, poor, fair, good, and outstanding. So according to Saaty's scale we assign a number each of them as follows:

1- not applicable

3- poor

5- fair

7- good

9- outstanding

3.3.5.6. Reliability

We gathered some information from the experts and the comuter journals (pcworld.com). They graded each element of the criteria as not applicable, poor, fair, good, and outstanding. So according to Saaty's scale we assign a number each of them as follows:

1- not applicable

2- poor

3- fair

4- good

5- outstanding

3.3.6. The Collection of Information and Computation

The data utilized to develop the PROMETHEE technique was gathered from experts in TOYOTA firm and in Department of Management Information Systems of Boğaziçi University and the journals related to the computer. At the same time a GDSS session was set up for collecting this information.

Since there are 279 computers and 86 criteria, it is impossible to solve this problem manually. So Java program was used for solving the problem. The solution will be explained in the results section.

3. 3.7. The AHP Method Summary

The laptop computer selection problem is represented as a hierarchy in which the top vertex is the main objective of the problem,the bottom vertices are the actions and the intermediary vertices represent the crirteria (which are more and more aggregated as one goes higher in the hierarchy) which should be taken into account.

At each level of the hierarchy, a pairwise comparison of the vertices is performed from the point of view of their "contribution"to each of the higher level vertices to which they are linked. The pairwise comparison is made in terms of "preference ratios" (if they are actions) or "importance ratios" (if they are criteria) evaluated on a numerical scale proposed within the method. A mathematical technique based upon the computation of the eigenvalues of the matrix of pairwise comparisons are made.

When each vertex of the hierarchy has been evaluated from the point of view of its contribution to the vertices of the immediately higher level, the global contribution of each action to the main objective is calculated by an aggregation of the weighted average type (Vincke, 1989).

3.4. REMBRANDT Method (Ratio Estimation in Magnitudes or deci-Bells to Rate Alternatives which are Non-Dominated)

3.4.1. Introduction

A group in the Netherlands led by F.A.Lottsma,has developed a system which uses **R**atio **E**stimation in **M**agnitudes or deci-**B**ells to **R**ate **A**lternatives which are **N**on-**D**ominated. This system is one of the MADM methods in MCDM.

3.4.2. The Differences between AHP and REMBRANDT

This system is intended to adjust for three contended flaws in AHP: First, direct rating is on a logarithmic scale which replaces the fundamental 1-9 scale presented by Saaty.
The second suggested improvement is the calculation of impact scores. The arithmetic mean is subject to rank reversal of alternatives. The geometric mean is not subject to rank reversal,nor is logaritmic regression.
The third improvement proposed by Lootsma is the aggregation of scores. This lowest level is normalized multiplicatively,so that the product of components equals 1 for each of the k factors over which the alternatives are compared. Therefore each alternative has an estimated relative performance w_k for each of the k factors. The components of the hierarchial level immediately superior to this lowest level are normalized additively ,so that they add to 1,yielding weights.

3.4.3. REMBRANDT Method Construction

REMBRANDT model construction is the same as AHP (See chapter 4 section 4.3.2).

3.4.4. Definition and Explanation of the Criteria and Sub-Criteria

This is explained in detail in AHP method.

3.4.5. Convertions

The same convertions is valid in AHP method.

3.4.6. Calculations

There are no noticeable differences between the techniques from the perspective of the users, as the same input is used.Important technical differences between AHP and REMBRANDT are summarized as

1.Different ratio scales

2.Alternative calculation of impact scores

3.A different aggregation procedure.

Therefore only the calculations are made in a different manner.

For solving this problem Java program was used. The results will be explained in the result section.

3.4.7. REMBRANDT-AHP Comparison

Rembrandt was found to recommend the same decision as AHP when the geometric mean was used for aggregation, but a different version was given by conventional AHP using arithmetic mean aggregation.

3.5. ELECTRE III Method

In our computer selection case there are 3 levels for criteria as mentioned before. But In ELECTRE method we use every criterion or subcriterion as the basis. So we have 86 criteria and 279 alternatives (computers). So first of all we calculate the weights of each criterion. But here we use the weights of the criteria found in AHP.

After collecting p, q, and veto thresholds from the experts we construct the method. Here p = 0.20, q = 0, 40 and v = 0,60 of the range of the criteria. First of all we calculate concordance matrix and then discordance matrix. Later by combining these two values we obtain credibility matrix. After finding credibility matrix we take $\lambda = 1$, and s (λ) = 0.15. So we find the T matrix. After finding T matrix first of all we find descending preorder and then ascending preorder. By combining these two preorders we finally obtain the final preorder. At the end of this final preorder we select the best laptop computer from 279 laptop computers.

Since there are 279 laptop computers and 86 criteria ,we. solve this problem by using Java program. At the end of the program we select the best laptop computer. The results will be explained in the Results Section in detail.

3.6. PROMETHEE Method

In this method like ELECTRE we use the same criteria and weights used in AHP. First of all we make interviews with the experts. Because in PROMETHEE there are 6 criterion types . According to the types of criterion we use different types of criterion weights. The data utilized to develop the PROMETHEE technique were gathered from experts in TOYOTA firm and in Department of Management Information Systems of Boğaziçi University and the journals related to the computer.At the same time a GDSS session was set up for collecting this information.

After collecting p, q, veto thresholds and criterion types, the PROMETHEE technique was applied to the laptop computer selection problem, by using Java program. Here p= 0.20, q=0, 40 and v= 0,60 of the range of the criteria values. First of all ingoing and outgoing flows are calculated i.e. PROMETHEE I is calculated. Later by subtracting ingoing flows from outgoing flows the netflows are calculated. By ranking the alternatives according to the netflows the laptop computer is selected (PROMETHEE II). The results will be explained in the Results Section in detail.

3.7. Conclusion

First of all we construted the model, i.e. hieararchy tree of the problem and we used 4 MCDM techniques for laptop computer selection problem by using the same data which was gathered by using GDSS experts for comparison.

3.8. RESULTS

After the data are collected for 279 laptop computers, for 86 criteria , the methods are solved by using Java program.

3.8.1. AHP Method Results

The weights for the main criteria (1 st level criteria) are as follows.

1 st Level criteria	**Weights**
1. Brand	**0,08**
2. Cost	**0,22**
3. Computer Performance	**0,20**
4. Warranty Conditions	**0,15**
5. Reliability	**0,19**
6. After sale service	**0,16**

Other criteria weights are as follows:

2 nd Level Criteria

For Cost	
Price	0,62
Operating costs	0,38
For Computer Performance	
1. Processor and memory	0,23
2. Graphics and sound	0,12
3. Communication and networking	0,16
4. Components	0,14
5. Software	0,12
6. Ports and interfaces	0,13
7. Power	0,06
8. Physical information	0,05
For Reliability	
1. Percent of PCs with problems	0,18
2. Problems per year	0,18
3. Problems on arrival	0,15
4. Dead on arrival	0,18
5. Component Failure	0,15
6. High satisfaction with reliability	0,18
For After Sale Service	
1. Short hold time	0,18
2. Quick resolution	0,18
3. No resolution	0,14
4. Knowledgeable tech. Support	0,14
5. Sincere effort by tech support	0,17
6. High sataisfaction with reliability	0,19
For Warranty Conditions	
1. Warranty Labor	0,23
2. Warranty parts	0,18
3. Warranty replacement	0,18
4. Support	0,21
5. Free phone support	0,20

In addition to these weights the third level criteria weights were also calculated.

The weights are shown in Appendix C.

According to AHP method, the Laptop computers are ranked as following.(for 10 computers).The results of 279 laptop computers are shown in Annex D.

Table 3.8. AHP Method Results

Brands	Value	Rank
IBM ThinkPad A21e (2628JSU)	0,695	**1**
IBM ThinkPad A21M (2528GLU)	0,660	**2**
IBM ThinkPad A21m (2628FSU)	0,658	**3**
IBM ThinkPad A21m (2628FXU)	0,657	**4**
IBM ThinkPad A21m (2628EXU)	0,654	**5**
IBM ThinkPad A21m (2628F2U)	0,652	**6**
IBM ThinkPad A21m (2628FWU)	0,649	**7**
IBM ThinkPad A21m (2628G2U)	0,649	**8**
IBM ThinkPad A21m (2628G1U)	0,637	**9**
Toshiba Satellite 4600 (PS460U-06KYH8)	0,636	**10**

3.8.2. REMBRANDT Method Results

The weights for the main criteria (1 st level criteria) are as follows for REMBRANDT method.

1 st Level criteria	Weight
1. Brand	0,170
2. Cost	0,169
3. Computer Performance	0,162
4. Warranty Conditions	0,166
5. Reliability	0,166
6. After sale service	0,168

According to REMBRANDT method, the Laptop computers are ranked as following.(for 10 computers). The results of 279 laptop computers are shown in Annex D.

Table 3.9. REMBRANDT Method Results

Brands	Value	Rank
IBM ThinkPad A21e (2628JSU)	0,815	**1**
IBM ThinkPad A21e (265593U)	0,781	**2**
Sony VAIO PCG-FX170	0,770	**3**
IBM ThinkPad A21m (2628G6U)	0,764	**4**
IBM ThinkPad A21m (2628FTU)	0,764	**5**
IBM ThinkPad A21m (2628EWU)	0,763	**6**
IBM ThinkPad A21m (2628G8U)	0,763	**7**
IBM ThinkPad A21M (2528GLU)	0,757	**8**
IBM ThinkPad A21m (2628FXU)	0,751	**9**
IBM ThinkPad A21m (2628G2U)	0,747	**10**

In the REMBRANDT method, IBM ThinkPad A21e (2628JSU) laptop computer is again the first one with the value of 0,815.

3.8.3. ELECTRE Method Results

In ELECTRE method, The AHP weights were used. According to ELECTRE method, the Laptop computers are ranked as following.(for 10 computers).The results of 279 laptop computers are shown in Annex D.

Table 3.10. ELECTRE Method Results

Brands	Value	Rank
Gateway Solo 9300cx	12	1
Acer TravelMate 610TXVI, P3, 800MHz	11	2
IBM ThinkPad A21m (2628FSU)	10	3
Toshiba Satellite 4600 (PS460U-06KYH8)	8	4
Gateway Solo 9300cx Deluxe	8	4
Apple iBook (M7699LL/A)	6	5
Apple iBook (M8520LL/A)	6	5
Compaq Armada E500 P3700	6	5
Toshiba Satellite 2800-S202	5	6
Toshiba Satellite 4600 (PS460U-079KD8)	5	6

In Electre method, Gateway Solo 9300cx is the first with the value of 12.

3.8.4. PROMETHEE Method Results

In PROMETHEE method, The AHP weights were used. The results are shown in Appendix B. But in PROMETHEE there are 6 types of criterion. The six types of criterion results are shown as follows (for 10 computers). The results of 279 laptop computers are shown in Annex D.

Table 3.11. PROMETHEE Method Results (For criterion 1 type)

Brands	Value	Rank
IBM ThinkPad A21e (2628JSU)	0,334	1
IBM ThinkPad A21e (2628CXU)	0,314	2
Dell Inspiron 2500: Cel 800MHz, 128MB, 10GB, 15TFT, WinME	0,290	3
IBM ThinkPad A21m (2628DWU)	0,290	4
IBM ThinkPad A21e (2628CTU)	0,280	5
IBM ThinkPad A21m (2628EXU)	0,268	6
IBM ThinkPad A21e (2628C1U)	0,264	7
IBM ThinkPad A21e (265571U)	0,260	8
IBM ThinkPad A21m (2628G2U)	0,259	9
IBM ThinkPad A21m (2628G1U)	0,257	10

Table 3.12. PROMETHEE Method Results (For criterion 2 type)

Brands	Value	Rank
IBM ThinkPad A21e (2628JSU)	0,320	**1**
IBM ThinkPad A21e (2628CXU)	0,286	**2**
Dell Inspiron 2500: Cel 800MHz, 128MB, 10GB,	0,262	**3**
IBM ThinkPad A21m (2628EXU)	0,252	**4**
IBM ThinkPad A21m (2628DWU)	0,252	**5**
IBM ThinkPad A21e (2628CTU)	0,247	**6**
IBM ThinkPad A21m (2628G2U)	0,246	**7**
IBM ThinkPad A21m (2628FXU)	0,244	**8**
IBM ThinkPad A21m (2628F2U)	0,236	**9**
IBM ThinkPad A21m (2628G1U)	0,234	**10**

Table 3.13. PROMETHEE Method Results (For criterion 3 type)

Brands	Value	Rank
IBM ThinkPad A21e (2628JSU)	0,300	**1**
IBM ThinkPad A21e (2628CXU)	0,259	**2**
Dell Inspiron 2500: Cel 800MHz, 128MB, 10GB, 15TFT, WinME	0,255	**3**
IBM ThinkPad A21m (2628DWU)	0,235	**4**
IBM ThinkPad A21m (2628EXU)	0,232	**5**
IBM ThinkPad A21e (2628CTU)	0,227	**6**
IBM ThinkPad A21m (2628FXU)	0,225	**7**
IBM ThinkPad A21m (2628G2U)	0,224	**8**
IBM ThinkPad A21m (2628F2U)	0,216	**9**
IBM ThinkPad A21m (2628G1U)	0,215	**10**

Table 3.14. PROMETHEE Method Results (For criterion 4 type)

Brands	Value	Rank
IBM ThinkPad A21e (2628JSU)	**0,284**	**1**
IBM ThinkPad A21e (2628CXU)	**0,227**	**2**
IBM ThinkPad A21m (2628EXU)	**0,226**	**3**
IBM ThinkPad A21m (2628FXU)	**0,222**	**4**
IBM ThinkPad A21m (2628G2U)	**0,220**	**5**
IBM ThinkPad A21m (2628DWU)	**0,220**	**6**
Dell Inspiron 2500: Cel 800MHz, 128MB, 10GB, 15TFT, WinME	**0,219**	**7**
IBM ThinkPad A21m (2628F2U)	**0,217**	**8**
IBM ThinkPad A21m (2628FSU)	**0,213**	**9**
IBM ThinkPad A21m (2628G1U)	**0,208**	**10**

Table 3.15. PROMETHEE Method Results (For criterion 5 type)

Brands	Value	Rank
IBM ThinkPad A21e (2628JSU)	**0,273**	**1**
Dell Inspiron 2500: Cel 800MHz, 128MB, 10GB, 15TFT, WinME	**0,228**	**2**
IBM ThinkPad A21m (2628EXU)	**0,213**	**3**
IBM ThinkPad A21m (2628FXU)	**0,212**	**4**
IBM ThinkPad A21e (2628CXU)	**0,209**	**5**
IBM ThinkPad A21m (2628FSU)	**0,207**	**6**
IBM ThinkPad A21m (2628DWU)	**0,206**	**7**
IBM ThinkPad A21m (2628G2U)	**0,206**	**8**
Dell Inspiron 2500: P3 1GHz, 128MB, 10GB, 15TFT, Win2000	**0,204**	**9**
IBM ThinkPad A21m (2628F2U)	**0,203**	**10**

Table 3.16. PROMETHEE Method Results (For criterion 6 type)

Brands	Value	Rank
IBM ThinkPad A21e (2628JSU)	**0,255**	**1**
Dell Inspiron 2500: Cel 800MHz, 128MB, 10GB, 15TFT, WinME	0,216	**2**
IBM ThinkPad A21e (2628CXU)	0,209	**3**
IBM ThinkPad A21m (2628DWU)	0,195	**4**
IBM ThinkPad A21m (2628EXU)	0,189	**5**
IBM ThinkPad A21e (2628CTU)	0,184	**6**
IBM ThinkPad A21m (2628FXU)	0,182	**7**
IBM ThinkPad A21m (2628G2U)	0,181	**8**
IBM ThinkPad A21m (2628FSU)	0,179	**9**
IBM ThinkPad A21m (2628G1U)	0,178	**10**

3.8.5. Comparison of the Results of the Methods:

In the laptop selection problem, the ranking of the alternatives are listed according to their weights or scores. When we look at the AHP Method, we see that the best computer is IBM ThinkPadA21e (2628JSU) with the value of 0,695. In REMBRANDT Method, the same computer (IBM ThinkPadA21e (2628JSU) with the value of 0,815, is the best of all the computers. In ELECTRE, Gateway solo 9300 cx is the first with the score of 12. The situation is different, because of the concordance, discordance,credibility measurements and distillation process. When it comes to Promethee Method, IBM ThinkPadA21e (2628JSU) is the first laptop. In Promethee Method, we applied the laptop selection problem for each type of criterion in order to see what type of criterion differs from the other types. But when we got solutions as above mentioned, we noticed that, for all types of 6 criterion, the results are the same. In this laptop computer selection problem, the results are not different for each type of criterion. So, we can say that, when we applied 4 Methods for this problem, except the Electre Method, the results of the Methods are the same. IBM ThinkPadA21e (2628JSU) with the price of 1887$ is the best computer that can be selected for the firm.

4 CONCLUSION

In this research, an application for laptop computer selection for a firm was tried to be carried out. MADM methods were applied to the selection of laptop computers for a firm (which is the procurement element of SCM) by using GDSS.

In our laptop computer selection application, there are 86 criteria and 279 alternatives (computers) There are 3 levels hierarchy for criteria. The first level hierarchy criteria data were gathered from the users, the second level hierarchy criteria data were garhered from both users and technicians and the third level hierarchy level criteria data were gathered from the technicians, experts, benchmarking tests and related computer journals. The collection of the data was challenging because, the data of each hierarchy level of the criteria were collected by using different groups. Especially for the 3 th level criteria, experts and technicians gave some scores between 0 and 10 for every technical item of the computer and also benchmarking tests were used for computing the weights of the every criterion. It had been encountered some difficulties in collecting data, because of dealing with the every feature of the computer, especially for the third level criteria Therefore, the right and experienced personnel, and technicians were selected for their assessments. In addition to this, there were some difficulties in converting qualitative data to numerical scale, this matter was handled by using the benchmarking tests and the opinions of the experts. After collecting data from different groups of people, arithmetic mean was used to calculate for finding the weights.

The methods implemented in this study are Analytic Hierarchy Process (AHP), REMBRANDT, ELECTRE III, and PROMETHEE.

4 methods were applied for this problem, except the Electre III method, the results of the methods look like similar.. In addition to this, we applied 6 possible types of generalized criteria for PROMETHEE method, in order to see whether there is a significant difference or not. However,for this problem the types of the criteria haven't affected the results significantly. For this situation, the results of the models except Electre look like similar..

MADM methods can be applied to the decision problems depending on the structure of the problem and the preferences of the decision maker.

Throughout the study some general features about the nature of methods have been observed and found to be remarkable. These general recommendations may help prospective practioners to setup their applications.

AHP Method is applied to the following type of decision problems:

- If the number of alternatives and criteria are limited
- If the problem consists a hierarchial structure
- If the problem is based on only pairwise comparisons
- If there is no outranking relation such as concordance and discordance measurements for the problem
- If the problem is simple because of its attributes
- The method is more flexible, because multilevel hierarchies are possible.

REMBRANDT Method is applied

- In cases where a more nearly logarithmic scale will be appropriate, such as planning horizons, loudness of sounds, and brightness of light.

ELECTRE Method is applied to the following type of decision problems:

- If the structure of the problem is imprecise and uncertain.
- If the possible differences on any of the criteria can give rise to discordance.
- If the decision maker wants to take all criteria into account by using outranking relations by using concordance, discordance
- If the decision maker wants to see the results by using distillation process.
- If the structure of the problem requires a veto threshold for calculation.
- If the decision maker express his preference between two alternatives on a given criterion on a ratio scale.

PROMETHEE Method is applied to the following type of decision problems:

- Where the decision maker can express his preference between two actions on a given criterion on a ratio scale.
- Where the decision maker wants to take all criteria into account and is aware of the fact that the weights are representing trade-offs.
- For all criteria the difference between evaluations must be meaningful.
- None of the possible differences on any of the criteria can give rise to discordance.
- The decision maker knows exactly what can happen if one or more alternatives are added or deleted and is fully aware of the influences on the final decision.

The Methods have been compared and these general characteristics have noticed.

- PROMETHEE is slightly easier to use than ELECTRE III.
- PROMETHEE surpasses ELECTRE III, because its threshold values have a significant meaning in terms of alternatives and it is not possible to take discordance into account when constructing the outrank relations.
- PROMETHEE has a better performance than AHP and REMBRANDT, in terms of interpretation of parameters and taking into consideration of outranking relations.
- PROMETHEE is a user-friendly outranking method and also suitable for building a decision support system.

Consequently, AHP and REMBRANDT are methods based on pairwise comparisons, but ELECTRE III and PROMETHEE are outranking methods. These methods are applied to the real life problems depending on the type, structure, complexity, of the problem, type of the data, the situation, and the preferences of the decision maker as listed above according to the each type of method.

It is expected that this study will contribute to the present procurement process that requires a new methodology by using different types of methods depending on the situation.

While this study provides 4 methods for MADM problems by using GDSS, additional research will be made to expand the research to include computer sellers, buyers, computer firms, and related perssonnel for their sharing information and obtaining precise data.

This study might be expanded by the procurement perssonnel who are making selection in different ways and this will enlighten their process and SOPs might be established in making decisions precisely in the future.

The research provides a means whereby companies or organizations can assess the selection of activities critical to their business by using GDSS. such as strategic planning, resource allocation, source selection, bussiness / publicy policy, program selection, supplier selection.

QUESTIONNAIRE **APPENDIX-A**

Aşağıda bir firmanın satın alma sürecinde bilgisayar (Laptop) alımı için karar verilirken göz önüne alacağı kriterler sıralanmıştır. Bu kriterler arasında bazı kriterlerin diğerlerine oranla daha fazla önemli olması kaçınılmazdır. Bu anket sonucunda vereceğiniz değerlendirme puanları, çalışma sonucunda önerilecek sistemin yapısını oluşturacak değerlendirme kriterlerinin yapısını ve bu kriterlerin ağırlıklarını oluşturacaktır. SİZE GÖRE UYGUN OLAN bir tedarik kararında iki kriterden hangisinin diğerine göre daha fazla önemli olduğunu düşünüyorsanız ona yakın olan numaralardan birini kriterin diğer kritere önem ağırlığına göre işaretleyiniz. Eğer önem derecelerinin eşit olduğunu düşünüyorsanız "1" seçeneğini işaretlemeniz gerekecektir.

ÖRN.	Uludağ	9	7	5	3	1	3	5	7	9	Kartalkaya

1=EŞİT 3=ORTA 5=GÜÇLÜ 7=ÇOK GÜÇLÜ 9=AŞIRI

1	Short Hold Time	9	7	5	3	1	3	5	7	9	Quick Resolution
2	Short Hold Time	9	7	5	3	1	3	5	7	9	No Resolution
3	Short Hold Time	9	7	5	3	1	3	5	7	9	Knowledgeable Tech Support
4	Short Hold Time	9	7	5	3	1	3	5	7	9	Sincere Effort by Tech. Support
5	Short Hold Time	9	7	5	3	1	3	5	7	9	High Satisfaction with Service
6	Quick Resolution	9	7	5	3	1	3	5	7	9	No Resolution
7	Quick Resolution	9	7	5	3	1	3	5	7	9	Knowledgeable Tech Support
8	Quick Resolution	9	7	5	3	1	3	5	7	9	Sincere Effort by Tech. Support
9	Quick Resolution	9	7	5	3	1	3	5	7	9	High Satisfaction with Service
10	No Resolution	9	7	5	3	1	3	5	7	9	Knowledgeable Tech Support
11	No Resolution	9	7	5	3	1	3	5	7	9	Sincere Effort by Tech. Support
12	No Resolution	9	7	5	3	1	3	5	7	9	High Satisfaction with Service
13	Knowledgeable Tech. Support	9	7	5	3	1	3	5	7	9	Sincere Effort by Tech. Support
14	Knowledgeable Tech. Support	9	7	5	3	1	3	5	7	9	High Satisfaction with Service
15	Sincere Effort by Tech.Support	9	7	5	3	1	3	5	7	9	High Satisfaction with Service

APPENDIX – B

LIST OF ALTERNATIVES

Model	Brand	Price	Processor Type	Processor Speed	RAM Installed
	Min	879		300	32
	Average	2032		729	108
	Max	3997		2059	256
Acer Travel Mate 350TE-N	Acer	2025.00	Intel Pentium III	650	128
Acer Travel Mate TM603TER	Acer	1899.00	Intel Pentium III	700	128
Acer TravelMate 210 (TM210T)	Acer	929.00	Intel Celeron	700	64
Acer TravelMate 351TEV-D (91.45H01.8Q5)	Acer	1776.99	Intel Pentium III	700	128
Acer TravelMate 351TEV-N (91.45H01.8S5)	Acer	1849.00	Intel Pentium III	700	128
Acer TravelMate 353TE-N, P3, 800MHz	Acer	1629.00	Intel Celeron	800	128
Acer TravelMate 524TE (524TE)	Acer	1469.09	Intel Pentium III	650	64
Acer TravelMate 525TXV-D, P3, 700MHz	Acer	1498.99	Intel Celeron	700	128
Acer TravelMate 527TXV (9141H01FQ5)	Acer	1929.00	Intel Pentium III	800	128
Acer TravelMate 610TXVI, P3, 800MHz	Acer	1839.95	Intel Celeron	800	128
Acer TravelMate 611TXCi, P3, 850MHz	Acer	2075.06	Intel Celeron	850	128
Acer TravelMate 611TXCi-D, P3, 850MHz	Acer	1916.99	Intel Celeron	850	128
Acer TravelMate 611TXV, P3, 850MHz	Acer	1452.31	Intel Celeron	850	128
Acer TravelMate 614TXCi, P3, 1GHz	Acer	2304.91	Intel Celeron	850	128
Acer TravelMate 736TL, P3, 650MHz	Acer	3399.00	Intel Pentium III	650	128
Acer TravelMate 738TLV-98 (738TLV-98)	Acer	2357.14	Intel Pentium III	750	128
Acer TravelMate 739GTLV (9149C01SD5)	Acer	3089.03	Intel Pentium III	1000	128
Acer TravelMate 739TLV (739TLV)	Acer	2715.55	Intel Pentium III	2059	128
Acer TravelMate TM603TER-98	Acer	1849.00	Intel Pentium III	700	128
Apple iBook	Apple	1469.00	PowerPC G3/750	300	64
Apple iBook (M7692LL/A)	Apple	1499.00	PowerPC G3/750	500	128
Apple iBook (M7698LL/A)	Apple	1299.00	PowerPC G3/750	500	64
Apple iBook (M7699LL/A)	Apple	1599.00	PowerPC G3/750	500	128
Apple iBook (M7721LL/A)	Apple	1359.00	PowerPC G3/750	366	64
Apple iBook (M8520LL/A)	Apple	1795.00	PowerPC G3/750	500	128
Apple iBook Apple Store	Apple	1795.00	PowerPC G3/750	500	128
Apple iBook Special Edition (M7720LL/A)	Apple	1649.00	G3/750	466	64

Model	Brand	Price	Processor Type	Process or Speed	RAM Installe d
Apple PowerBook (400 Mhz)	Apple	1720.00	PowerPC G3/750	400	64
Apple PowerBook (500MHz, 20GB)	Apple	2499.00	PowerPC G3/750	500	128
Apple PowerBook (500MHz, 30GB)	Apple	3997.00	PowerPC G3/750	500	128
Apple PowerBook G4 "Titanium" (M7710LL/A)	Apple	3495.00	PowerPC G4	500	256
Apple PowerBook G4 "Titanium" (M7952LL/A)	Apple	2594.00	PowerPC G4	400	128
Compaq Presario 1700 17XL365	Compaq	2164.14	Intel Pentium III	700	128
Compaq Armada E500 Intel Pentium III (470011-577)	Compaq	3199.00	Intel Pentium III	1000	128
Compaq Armada E500 Intel Pentium III (470011-622)	Compaq	3299.00	Intel Pentium III	1000	128
Compaq Armada E500 Intel Pentium III (470011-648)	Compaq	2399.00	Intel Pentium III	900	128
Compaq Armada E500 Intel Pentium III (470011-680)	Compaq	2499.00	Intel Pentium III	900	128
Compaq Armada E500 P3650 (12GB, 14.1in, 4X DVD-ROM, Win98)	Compaq	2049.00	Intel Pentium III	650	64
Compaq Armada E500 P3700 (12GB, 14in, 8X DVD-ROM, Win2000, RJ45)	Compaq	2619.51	Intel Pentium III	700	64
Compaq Armada E500 P3700 (12GB, 14in, 8X DVD-ROM, Win98, RJ45)	Compaq	2399.00	Intel Pentium III	700	64
Compaq Armada E500 P3700 (12GB, 15in, 8X DVD-ROM, Win2000, RJ45)	Compaq	2619.51	Intel Pentium III	700	64
Compaq Armada E500 P3800/14T (179855-001)	Compaq	2129.79	Intel Pentium III	800	64
Compaq Armada E500 P3800/14T (179855-008)	Compaq	2229.79	Intel Pentium III	800	64
Compaq Armada E500 P3850/15T (179858-001)	Compaq	2929.99	Intel Pentium III	850	128
Compaq Armada E500 P3850/15T (179858-008)	Compaq	3009.47	Intel Pentium III	850	128
Compaq Armada M300 (500MHz, Win98, 12GB)	Compaq	1969.55	Intel Pentium III	500	64
Compaq Armada M300 (6GB, 11.3 XGA, Win 2000)	Compaq	1853.69	Intel Pentium III	600	64
Compaq Armada M300 (6GB, 11.3 XGA, Win 98)	Compaq	1704.93	Intel Pentium III	600	64
Compaq Armada M300 P3500/T11 (165288-008)	Compaq	1499.00	Intel Pentium III	500	64
Compaq Armada M300 P3600/T11 (180428-008)	Compaq	1853.69	Intel Pentium III	600	64
Compaq Armada M300 P3600/T12 (180400-002)	Compaq	2019.99	Intel Pentium III	600	64
Compaq Armada M700 P3500 (12GB, 4X DVD-ROM, WinNT, RJ45)	Compaq	1699.00	Intel Pentium III	500	64
Compaq Armada M700 P3650 (6GB, 24X CD-ROM, WinNT, RJ45)	Compaq	2199.00	Intel Pentium III	650	64
Compaq Armada M700 P3700 (12GB, 8X DVD-ROM, Win2000, RJ45)	Compaq	2349.99	Intel Pentium III	700	64
Compaq Armada M700 P3700 (12GB, 8X DVD-ROM, Win98, RJ45)	Compaq	2349.99	Intel Pentium III	700	64
Compaq Armada M700 P3850/14T (470006-422)	Compaq	2999.00	Intel Pentiu	850	128
Compaq Presario 1200 Series (12XL410)	Compaq	1633.96	Intel Penti	700	128

Model	Brand	Price	Processor Type	Processor Speed	RAM Installed
Compaq Presario 1200: Ath 1.1GHz, 128MB, 10GB, 13.3TFT, WinME	Compaq	1523.00	AMD Athlon	1100	128
Compaq Presario 1200US	Compaq	1049.00	Intel Celeron	800	128
Compaq Presario 1200-XL105	Compaq	1098.00	AMD K6-2	475	32
Compaq Presario 1200-XL110	Compaq	989.00	AMD K6-2	475	64
Compaq Presario 1200-XL111	Compaq	1185.00	AMD K6-2	500	64
Compaq Presario 1200XL126 (AMD 533, 96MB, 6GB, 13 HPA)	Compaq	1058.00	AMD K6-2	533	96
Compaq Presario 1210US	Compaq	1199.00	AMD Duron	850	128
Compaq Presario 12XL325	Compaq	1398.00	Intel Pentium III	650	64
Compaq Presario 12XL326 (212636-007)	Compaq	1299.00	Intel Celeron	600	128
Compaq Presario 12XL427	Compaq	3499.00	Intel Celeron	667	96
Compaq Presario 12XL430 (470008-502)	Compaq	3499.00	Intel Pentium III	750	128
Compaq Presario 12XL500 (470011-693)	Compaq	1199.00	Intel Celeron	766	64
Compaq Presario 12XL505 (470009-467)	Compaq	1399.00	Intel Celeron	766	128
Dell Inspiron 2100: P3 700MHz, 128MB, 10GB, 12.1TFT, Win2000	Dell	2074.00	Intel Pentium III	700	128
Dell Inspiron 2100: P3 700MHz, 128MB, 10GB, 12.1TFT, WinME	Dell	1748.00	Intel Pentium III	700	128
Dell Inspiron 2500: Cel 800MHz, 128MB, 10GB, 15TFT, WinME	Dell	1646.00	Intel Celeron	800	128
Dell Inspiron 2500: P3 1GHz, 128MB, 10GB, 15TFT, Win2000	Dell	2096.00	Intel Pentium III	1000	128
Dell Inspiron 4000 (63387-890512)	Dell	1299.00	Intel Celeron	700	64
Dell Inspiron 4000 Cel 800MHz, 128MHz, 20GB, 14.1TFT, WinME	Dell	1702.00	Intel Celeron	800	128
Dell Inspiron 4000: P3 1 GHz, 128MB, 10GB, 14.1TFT, Win2000	Dell	2275.00	Intel Pentium III	1000	128
Dell Inspiron 8100: P3 1.13GHz, 128MB, 10GB, Win2000	Dell	2983.00	Intel Pentium III	1130	128
Dell Inspiron 8100: P3 866MHz, 256MB, 30GB, WinME	Dell	2123.00	Intel Pentium III	866	256
Dell Latitude C500: Cel 800MHz, 128MB, 10GB, 14.1TFT, Win2000	Dell	2363.00	Intel Celeron	800	128
Dell Latitude C600: P3 850MHz, 256MB, 20GB, 14.1TFT, Linux	Dell	2356.00	Intel Pentium III	850	256
Dell Latitude C800: P3 1GHz, 128MB, 20GB, 15.1TFT, Win2000	Dell	2466.00	Intel Pentium III	1000	128
Dell Latitude C810: P3 1.13GHz, 128MB, 10GB,15TFT, Win2000	Dell	2593.00	Intel Pentium III	1130	128
Dell Latitude L400: P3 700MHz, 128MB, 10GB, 12.1TFT, Win2000	Dell	2386.00	Intel Pentium III	700	128
Gateway Solo 1150cl	Gateway	1199.00	Intel Celeron	550	64
Gateway Solo 1150cs	Gateway	999.00	Intel Celeron	650	64
Gateway Solo 3350	Gateway	1999.00	Intel Pentium III	700	128
Gateway Solo 3350 Deluxe	Gateway	2128.00	Intel Pentium III	700	128

Model	Brand	Price	Processor Type	Processor Speed	RAM Installed
Gateway Solo 3350 Special Deluxe	Gateway	1928.00	Intel Pentium III	600	128
Gateway Solo 3350cs	Gateway	1999.00	Intel Pentium III	600	64
Gateway Solo 3350cs Deluxe	Gateway	2128.00	Intel Pentium III	600	64
Gateway Solo 3350cs Special	Gateway	1729.00	Intel Pentium III	600	128
Gateway Solo 5300 cs deluxe	Gateway	1528.00	Intel Celeron	650	64
Gateway Solo 5300cl	Gateway	1899.00	Intel Celeron	700	64
Gateway Solo 5300cl deluxe	Gateway	2028.00	Intel Celeron	700	64
Gateway Solo 5300cs	Gateway	1399.00	Intel Celeron	650	64
Gateway Solo 5300cx	Gateway	2199.00	Intel Celeron	750	128
Gateway Solo 5300cx deluxe	Gateway	2328.00	Intel Celeron	750	128
Gateway Solo 5300ls	Gateway	1499.00	Intel Celeron	700	128
Gateway Solo 5300ls deluxe	Gateway	1628.00	Intel Celeron	700	128
Gateway Solo 5300se	Gateway	1299.00	Intel Celeron	700	128
Gateway Solo 5300se deluxe	Gateway	1428.00	Intel Celeron	700	128
Gateway Solo 5300xl	Gateway	1699.00	Intel Celeron	850	128
Gateway Solo 5300xl Deluxe	Gateway	1829.00	Intel Celeron	850	128
Gateway Solo 9300cx	Gateway	2999.00	Intel Pentium III	850	96
Gateway Solo 9300cx Deluxe	Gateway	3028.00	Intel Pentium III	850	96
Gateway Solo 9500 ls Deluxe	Gateway	2228.00	Intel Pentium III	750	128
Gateway Solo 9500cl	Gateway	1999.00	Intel Pentium III	850	128
Gateway Solo 9500cl Deluxe	Gateway	2128.00	Intel Pentium III	850	128
Gateway Solo 9500cs	Gateway	1799.00	Intel Pentium III	700	128
Gateway Solo 9500cs Deluxe	Gateway	1928.00	Intel Pentium III	700	128
Gateway Solo 9500ls	Gateway	2099.00	Intel Pentium III	750	128
Gateway Solo 9500se	Gateway	1899.00	Intel Pentium III	750	128
Gateway Solo 9500se Deluxe	Gateway	2028.00	Intel Pentium III	750	128
Gateway Solo 9500xl	Gateway	2699.00	Intel Pentium III	900	256
Gateway Solo 9500xl Deluxe	Gateway	2828.00	Intel Pentium III	900	256
Hewlett Packard Omnibook 500 (F2161WT#ABA)	Hewlett Packard	1299.00	Intel Pentium III	600	64
Hewlett Packard Omnibook 500 (F2162K)	Hewlett Packard	2339.00	Intel Pentium III	600	64
Hewlett Packard Omnibook 500 (F2162W)	Hewlett Packard	2249.00	Intel Pentium III	600	64
Hewlett Packard Omnibook 500 (F2164KT#ABA)	Hewlett Packard	2166.99	Intel Pentium III	600	128
Hewlett Packard Omnibook 500 (F2164WT#ABA)	Hewlett Packard	2069.00	Intel Pentium III	600	128

Model	Brand	Price	Processor Type	Processor Speed	RAM Installed
Hewlett Packard Omnibook 500 (F2165W)	Hewlett Packard	2239.00	Intel Pentium III	600	128
Hewlett Packard Omnibook 500 (F2167W/K)	Hewlett Packard	2494.00	Intel Pentium III	700	128
Hewlett Packard Omnibook 500 (F2168K)	Hewlett Packard	2490.00	Intel Pentium III	700	128
Hewlett Packard Omnibook 500 (F2168W)	Hewlett Packard	2390.00	Intel Pentium III	700	128
Hewlett Packard OmniBook 6000 (F2081KT)	Hewlett Packard	1599.00	Intel Pentium III	600	64
Hewlett Packard OmniBook 6000 (F2182KT)	Hewlett Packard	2599.00	Intel Pentium III	800	128
Hewlett Packard OmniBook 6000 (F2184KT)	Hewlett Packard	2799.00	Intel Pentium III	850	128
Hewlett Packard OmniBook 6000 (F2188KT)	Hewlett Packard	2299.00	Intel Pentium III	750	64
Hewlett Packard OmniBook 6000 (F2188WT)	Hewlett Packard	2349.00	Intel Pentium III	750	64
Hewlett Packard OmniBook 6000 (F2197KT)	Hewlett Packard	2199.00	Intel Pentium III	700	64
Hewlett Packard OmniBook 6000 (F2197WT)	Hewlett Packard	2099.00	Intel Pentium III	700	64
Hewlett Packard OmniBook 6000 (F2200KT)	Hewlett Packard	2559.00	Intel Pentium III	900	128
Hewlett Packard OmniBook 6000 (F2200WT)	Hewlett Packard	2449.00	Intel Pentium III	900	128
Hewlett Packard OmniBook 6100: P3 1.13GHZ(F3263KT#ABA)	Hewlett Packard	3459.00	Intel Celeron	1130	256
Hewlett Packard OmniBook 6100: P3 1.13GHZ(F3263WT#ABA)	Hewlett Packard	3359.00	Intel Celeron	1130	256
Hewlett Packard OmniBook 6100: P3 1GHz(F3260KT#ABA)	Hewlett Packard	3279.00	Intel Celeron	1000	256
Hewlett Packard OmniBook 6100: P3 1GHz(F3260WT#ABA)	Hewlett Packard	3075.00	Intel Celeron	1000	256
Hewlett Packard OmniBook 6100: P3 900GHz(F3257WT#ABA)	Hewlett Packard	2649.00	Intel Celeron	933	128
Hewlett Packard OmniBook 6100: P3 900MHz(F3257KT#ABA)	Hewlett Packard	2749.00	Intel Celeron	933	128
Hewlett Packard OmniBook 6100: P3 900MHz(F3259KT#ABA)	Hewlett Packard	2850.00	Intel Celeron	933	128
Hewlett Packard OmniBook 6100: P3 900MHz(F3259WT#ABA)	Hewlett Packard	2755.00	Intel Celeron	933	128
Hewlett Packard OmniBook 6100: P3 900MHz(F3266WT#ABA)	Hewlett Packard	2799.00	Intel Celeron	933	128
Hewlett Packard Omnibook xe3 Series (F2300W/K)	Hewlett Packard	1149.00	Intel Celeron	650	64
Hewlett Packard Omnibook xe3 Series (F2302W/K)	Hewlett Packard	1349.00	Intel Celeron	650	64
Hewlett Packard OmniBook xe3 Series (F2330WT)	Hewlett Packard	1199.00	Intel Pentium III	700	64
Hewlett Packard OmniBook xe3 Series (F2332WT)	Hewlett Packard	1399.00	Intel Pentium III	700	128

Model	Brand	Price	Processor Type	Processor Speed	RAM Installed
Hewlett Packard OmniBook xe3 Series (F2333WT)	Hewlett Packard	1699.00	Intel Pentium III	750	128
Hewlett Packard OmniBook xe3 Series (F2337WT)	Hewlett Packard	1599.00	Intel Pentium III	850	128
Hewlett Packard OmniBook XE3: 900MHz (F2340KT#ABA)	Hewlett Packard	2049.00	Intel Pentium III	900	256
Hewlett Packard OmniBook XE3: Cel 800(F3777WT#ABA)	Hewlett Packard	1339.00	Intel Celeron	800	128
Hewlett Packard OmniBook Xe3: Cel 80MHz(F3776KT#ABA)	Hewlett Packard	1229.00	Intel Celeron	800	128
Hewlett Packard OmniBook XE3: P3 1GHz(F3778KT#ABA)	Hewlett Packard	2349.00	Intel Pentium III	1000	256
Hewlett Packard OmniBook XE3: P3 1GHz(F3778WT#ABA)	Hewlett Packard	2249.00	Intel Pentium III	1000	256
Hewlett Packard OmniBook XE3: P3 850MHz(F2339WT)	Hewlett Packard	1799.00	Intel Pentium III	850	256
Hewlett Packard Pavilion n5310	Hewlett Packard	1349.00	Intel Pentium III	750	128
Hewlett Packard Pavilion N5340: P3 850MHz(F2418M)	Hewlett Packard	1499.00	Intel Pentium III	850	128
Hewlett Packard Pavilion N5420L: Cel 800MHz(F2404M#ABA)	Hewlett Packard	1999.00	Intel Celeron	800	128
Hewlett Packard Pavilion N5440: P3 850MHz, 15TFT(F2405M#ABA)	Hewlett Packard	1599.00	Intel Pentium III	850	128
Hewlett Packard Pavilion N5450: P3 850MHz(F2406M#ABA)	Hewlett Packard	1799.00	Intel Pentium III	850	128
Hewlett Packard Pavilion N5470: Ath4 1GHz (F2407M#ABA)	Hewlett Packard	2099.00	AMD Duron	1000	128
Hewlett Packard Pavilion N5490: P3 1 GHZ(F2408M)	Hewlett Packard	2199.00	Intel Pentium III	1000	256
Hewlett Packard Pavilion N6395: 1GHz, 256MB, 30GB, 15TFT, WinME(F2971M)	Hewlett Packard	2339.00	Intel Pentium III	1000	256
IBM ThinkPad A20m (26284SU)	IBM	2396.56	Intel Pentium III	700	64
IBM ThinkPad A20m (26284TU)	IBM	2474.89	Intel Pentium III	700	64
IBM ThinkPad A20m (26284UU)	IBM	2424.37	Intel Pentium III	600	64
IBM ThinkPad A21e (2628C1U)	IBM	1439.84	Intel Celeron	600	64
IBM ThinkPad A21e (2628C2U)	IBM	1537.58	Intel Celeron	600	64
IBM ThinkPad A21e (2628CSU)	IBM	1539.65	Intel Celeron	600	64
IBM ThinkPad A21e (2628CTU)	IBM	1639.02	Intel Celeron	600	64
IBM ThinkPad A21e (2628CXU)	IBM	1529.14	Intel Celeron	600	64
IBM ThinkPad A21e (2628J1U)	IBM	1759.45	Intel Celeron	600	64
IBM ThinkPad A21e (2628J2U)	IBM	1857.25	Intel Celeron	600	64
IBM ThinkPad A21e (2628JAU)	IBM	1857.25	Intel Celeron	700	64
IBM ThinkPad A21e (2628JCU)	IBM	1955.05	Intel Celeron	700	64
IBM ThinkPad A21e (2628JSU)	IBM	1887.00	Intel Celeron	600	64
IBM ThinkPad A21e (2628JTU)	IBM	1984.26	Intel Celeron	600	64
IBM ThinkPad A21e (2628JUU)	IBM	1975.94	Intel Celeron	700	64
IBM ThinkPad A21e (2628JVU)	IBM	2086.99	Intel Celeron	700	64
IBM ThinkPad A21e (2628JWU)	IBM	1969.36	Intel Celeron	600	64

Model	Brand	Price	Processor Type	Processor Speed	RAM Installed
IBM ThinkPad A21e (2628JXU)	IBM	1853.45	Intel Celeron	600	64
IBM ThinkPad A21e (265571U)	IBM	1580.53	Intel Celeron	650	64
IBM ThinkPad A21e (265573U)	IBM	1679.39	Intel Celeron	650	64
IBM ThinkPad A21e (265593U)	IBM	1987.99	Intel Celeron	700	64
IBM ThinkPad A21M (2528GLU)	IBM	3046.00	Intel Pentium III	800	128
IBM ThinkPad A21m (2628DTU)	IBM	1888.99	Intel Pentium III	700	64
IBM ThinkPad A21m (2628DWU)	IBM	1857.25	Intel Pentium III	700	64
IBM ThinkPad A21m (2628DXU)	IBM	1759.45	Intel Pentium III	700	64
IBM ThinkPad A21m (2628E1U)	IBM	1969.61	Intel Pentium III	700	64
IBM ThinkPad A21m (2628E2U)	IBM	2036.05	Intel Pentium III	700	64
IBM ThinkPad A21m (2628EWU)	IBM	2171.72	Intel Pentium III	700	64
IBM ThinkPad A21m (2628EXU)	IBM	2033.80	Intel Pentium III	700	64
IBM ThinkPad A21m (2628F1U)	IBM	2052.85	Intel Pentium III	750	64
IBM ThinkPad A21m (2628F2U)	IBM	2139.99	Intel Pentium III	750	64
IBM ThinkPad A21m (2628FSU)	IBM	2186.99	Intel Pentium III	750	64
IBM ThinkPad A21m (2628FTU)	IBM	2248.45	Intel Pentium III	750	64
IBM ThinkPad A21m (2628FWU)	IBM	2306.32	Intel Pentium III	750	64
IBM ThinkPad A21m (2628FXU)	IBM	2185.10	Intel Pentium III	750	64
IBM ThinkPad A21m (2628G1U)	IBM	1999.99	Intel Pentium III	800	64
IBM ThinkPad A21m (2628G2U)	IBM	2099.00	Intel Pentium III	800	64
IBM ThinkPad A21m (2628G6U)	IBM	2155.29	Intel Pentium III	800	64
IBM ThinkPad A21m (2628G7U)	IBM	2219.00	Intel Pentium III	800	64
IBM ThinkPad A21m (2628G8U)	IBM	2219.11	Intel Pentium III	800	64
KDS Valiant 6370iPT	KDS	1122.39	Intel Pentium III	700	64
KDS Valiant 6480iPTD-01	KDS	1399.96	Intel Pentium III	800	128
KDS Valiant 6480iPTD-02	KDS	1899.00	Intel Pentium III	800	128
Panasonic Toughbook 48 (600MHz, 14.1)	Panasonic	2168.57	Intel Pentium III	600	64
Panasonic Toughbook 72	Panasonic	2869.00	Intel Pentium III	700	128
Panasonic Toughbook 72, P3, 700MHz, 128Mb, 20GB, 13.3TFT, Win2000(	Panasonic	3099.00	Intel Pentium III	700	128
Sony VAIO PCG-505TL	Sony	1499.00	Intel Pentium III	450	64
Sony VAIO PCG-C1VN	Sony	1769.99	Transmeta Crusoe	600	128

Model	Brand	Price	Processor Type	Processor Speed	RAM Installed
Sony VAIO PCG-C1VP	Sony	1899.99	Transmeta Crusoe	667	128
Sony VAIO PCG-C1VPK	Sony	1999.99	Transmeta Crusoe	667	128
Sony VAIO PCG-C1XS	Sony	1679.99	Intel Pentium II	400	64
Sony VAIO PCG-F420	Sony	989.00	Intel Pentium III	450	64
Sony VAIO PCG-F430	Sony	1349.00	Intel Pentium III	450	64
Sony VAIO PCG-F450	Sony	1335.00	Intel Pentium III	500	64
Sony VAIO PCG-F480K	Sony	2149.99	Intel Pentium III	600	64
Sony VAIO PCG-F490	Sony	2049.99	Intel Pentium III	650	128
Sony VAIO PCG-F520	Sony	1049.00	Intel Pentium III	500	64
Sony VAIO PCG-F540	Sony	1375.00	Intel Pentium III	500	64
Sony VAIO PCG-F540K	Sony	1529.99	Intel Pentium III	500	64
Sony VAIO PCG-F560	Sony	1448.00	Intel Pentium III	600	64
Sony VAIO PCG-F560K	Sony	1570.00	Intel Pentium III	600	64
Sony VAIO PCG-F580	Sony	1835.00	Intel Pentium III	650	64
Sony VAIO PCG-F580K	Sony	1949.99	Intel Pentium III	650	64
Sony VAIO PCG-F590	Sony	2075.00	Intel Pentium III	750	128
Sony VAIO PCG-F590K	Sony	2295.00	Intel Pentium III	750	128
Sony VAIO PCG-F610	Sony	879.00	AMD K6-2	550	64
Sony VAIO PCG-F630	Sony	1189.99	AMD K6-2	550	64
Sony VAIO PCG-F650	Sony	1560.00	Intel Pentium III	600	64
Sony VAIO PCG-F680	Sony	1895.00	Intel Pentium III	700	64
Sony VAIO PCG-F690	Sony	2599.99	Intel Pentium III	850	128
Sony VAIO PCG-F690K	Sony	3429.00	Intel Pentium III	850	128
Sony VAIO PCG-FX120	Sony	1510.50	Intel Pentium III	700	64
Sony VAIO PCG-FX120K	Sony	1579.00	Intel Pentium III	700	64
Sony VAIO PCG-FX140	Sony	1722.50	Intel Pentium III	700	128
Sony VAIO PCG-FX140K	Sony	1849.00	Intel Pentium III	700	128
Sony VAIO PCG-FX150	Sony	1998.9	Intel Pentium III	750	128
Sony VAIO PCG-FX150K	Sony	2199.00	Intel Pentium III	750	64
Sony VAIO PCG-FX170	Sony	2479.99	Intel Pentium III	800	128
Sony VAIO PCG-FX170K	Sony	2680.74	Intel Pentium	800	128

Model	Brand	Price	Processor Type	Processor Speed	RAM Installed
Sony VAIO PCG-FX190	Sony	2799.00	Intel Pentium III	850	128
Sony VAIO PCG-FX190K	Sony	2895.00	Intel Pentium III	850	128
Sony VAIO PCG-FX210	Sony	1246.00	AMD Duron	800	128
Sony VAIO PCG-FX210K	Sony	1549.00	AMD Duron	800	128
Sony VAIO PCG-FX215	Sony	1396.00	AMD Duron	800	128
Sony VAIO PCG-FX220	Sony	1496.00	Intel Pentium III	750	128
Sony VAIO PCG-FX220K	Sony	1596.00	Intel Pentium III	750	128
Sony VAIO PCG-FX240	Sony	1796.00	Intel Pentium III	800	128
Sony VAIO PCG-FX240K	Sony	1896.00	Intel Pentium III	800	128
Sony VAIO PCG-FX250	Sony	1896.00	Intel Pentium III	800	128
Sony VAIO PCG-FX250K	Sony	1996.00	Intel Pentium III	800	128
Sony VAIO PCG-FX270	Sony	2296.00	Intel Pentium III	850	192
Sony VAIO PCG-FX270K	Sony	2396.00	Intel Pentium III	850	192
Sony VAIO PCG-FX290	Sony	2999.00	Intel Pentium III	850	128
Sony VAIO PCG-FX290K	Sony	3099.00	Intel Pentium III	850	128
Sony VAIO PCG-FX340	Sony	1549.99	Intel Pentium III	900	128
Sony VAIO PCG-FX340K	Sony	1649.99	Intel Pentium III	900	128
Toshiba Portege 7220CTe (650MHz, Microsoft Windows 2000)	Toshiba	2499.00	Intel Pentium III	650	64
Toshiba Portege 7220CTe (650MHz, Microsoft Windows 98)	Toshiba	2266.06	Intel Pentium III	650	64
Toshiba Satellite 1755	Toshiba	1399.00	Intel Celeron	700	64
Toshiba Satellite 2800-S201	Toshiba	1132.26	Intel Celeron	650	64
Toshiba Satellite 2800-S201 (PS280U-8G5L06)	Toshiba	1132.26	Intel Celeron	650	64
Toshiba Satellite 2800-S202	Toshiba	1799.00	Intel Pentium III	700	128
Toshiba Satellite 2805 (2805-S201)	Toshiba	1199.00	Intel Celeron	650	64
Toshiba Satellite 2805 (2805-S301)	Toshiba	1699.00	Intel Pentium III	650	128
Toshiba Satellite 2805 (2805-S401)	Toshiba	2159.99	Intel Pentium III	700	128
Toshiba Satellite 2805-S202	Toshiba	1799.00	Intel Pentium III	700	128
Toshiba Satellite 2805-S302	Toshiba	1899.00	Intel Pentium III	650	128
Toshiba Satellite 2805-S402	Toshiba	2749.00	Intel Pentium III	850	128
Toshiba Satellite 4600 (PS460U-06KYH8)	Toshiba	2269.79	Intel Pentium III	800	128
Toshiba Satellite 4600 (PS460U-06QVX8)	Toshiba	2581.08	Intel Pentium III	850	128
Toshiba Satellite 4600 (PS460U-079KD8)	Toshiba	1990.52	Intel Pentium III	750	128

Model	Brand	Price	Processor Type	Processor Speed	RAM Installed
Toshiba Satellite Pro 4300 (600MHz	Toshiba	1699.00	Intel Pentium III	600	64
Versa SXi	NEC	3365.30	Intel Pentium III	800	128
Versa SXi (700MHz)	NEC	3049.99	Intel Pentium III	700	128
Versa SXi (850 MHz, 128MB, 20HD, 14.1)	NEC	3899.00	Intel Pentium III	850	128

APPENDIX-C

HIERARCHY OF CRITERIA AND WEIGHTS

Obj		Criteria	Weight
		Brand	**0,08**
		Cost	**0,22**
		Computer	**0,20**
		Warranty	**0,15**
		Reliability	**0,19**
		Service	**0,16**

min	0,22	Price	0,62
min		OperatingCost	0,38

max	0,19	Percent of PCs with problems	0,18
max		Problems per year	0,18
max		Problems on arrival	0,15
max		Dead on arrival	0,18
max		Component failure	0,15
max		High satisfaction with reliability	0,18

max	0,16	Short hold time	0,18
max		Quick resolution	0,18
max		No resolution	0,14
max		Knowledgeable tech support	0,14
max		Sincere effort by tech support	0,17
max		High satisfaction with service	0,19

max	0,15	Warranty-Labor	0,23
max		Warranty-Parts	0,18
max		Warranty-Replacement	0,18
max		Support	0,21
max		Free Phone Support	0,20

	0,20	Processor and Memory	0,23
		Graphics and Sound	0,12
		Communications and Networking	0,16
		Components	0,14
		Software	0,12
		Ports and Interfaces	0,13

		Power	0,06
		Physical	0,05
max	0,04	Processor Type	0,121
max		Processor Speed	0,126
max		Installed RAM	0,130
max		RAM Type	0,100
max		Max RAM	0,096
max		Number of RAM Sockets	0,113
max		L2 Cache Size	0,088
max		Bus Speed	0,105
max		Hard Drive Capacity	0,121
max	0,02	Video RAM	0,157
max		Display Mode	0,178
max		Graphics Card	0,157
max		Graphics Interface	0,157
max		Screen Size	0,178
max		Screen Technology	0,173
max	0,03	Network Ready	0,189
max		Network Support	0,105
max		Modem Type	0,147
max		Modem Speed	0,158
max		Wireless Capability	0,084
max		Security Options	0,168
max		Security Features	0,147
max	0,03	Included Drives	0,172
max		Integrated Floppy	0,162
max		CD-ROM Read Speed	0,157
max		DVD-ROM Read Speed	0,126
max		Speakers	0,086
max		Port Replicator/Docking Station	0,101
max		Camera	0,086
max		Keyboard	0,111
max	0,03	Network Connectors	0,141
max		Video Ports	0,104
max		USB	0,122
max		SCSI	0,085

max		Parallel	0,122
max		Serial	0,122
max		Mouse/Keyboard (PS/2)	0,122
max		Audio Connectors	0,078
max		Zoomed Video Port	0,059
max		Infrared Connector	0,044

max	0,02	Operating System	1,000

max	0,01	Battery Type	0,267
min		Battery Cells	0,200
max		Battery Life	0,300
max		Longer Battery Options	0,233

max	0,01	Depth	0,092
min		Height	0,087
max		Width	0,092
min		Weight	0,098
max		Pointing Device	0,196
max		PC Card Slots	0,152
max		Form Factor	0,196
max		Configurable	0,087

COMPARISON OF ALGORITHMS RESULTS

MODEL	Price	AHP		REMBRANDT		ELECTRE		PROM-1		PROM-2		PROM-3		PROM-4		PROM-5		PROM-6	
								Usual Cr		U-Shape Cr		V-Shape Cr		Level Cr		V-shape+indif		Gaussian	
IBM ThinkPad A21e (2628JSU)	1887	1	0.695	1	0.815	90	0	1	0.334	1	0.320	1	0.300	1	0.284	1	0.273	1	0.255
IBM ThinkPad A21m (2628EXU)	2034	5	0.654	17	0.737	16	3	6	0.268	4	0.252	5	0.232	3	0.226	3	0.213	5	0.189
IBM ThinkPad A21m (2628FXU)	2185	4	0.657	9	0.751	90	0	12	0.254	8	0.244	7	0.225	4	0.222	4	0.212	7	0.182
IBM ThinkPad A21m (2628G2U)	2099	8	0.649	10	0.747	90	0	9	0.259	7	0.246	8	0.224	5	0.220	8	0.206	8	0.181
IBM ThinkPad A21e (2628CXU)	1529	21	0.622	39	0.715	45	1	2	0.314	2	0.286	2	0.259	2	0.227	5	0.209	3	0.209
IBM ThinkPad A21m (2628FSU)	2187	3	0.658	14	0.740	3	10	14	0.236	11	0.227	11	0.215	9	0.213	6	0.207	9	0.179
IBM ThinkPad A21m (2628DWU)	1857	13	0.635	34	0.724	45	1	4	0.290	5	0.252	4	0.235	6	0.220	7	0.206	4	0.195
IBM ThinkPad A21m (2628F2U)	2140	6	0.652	19	0.736	45	1	13	0.241	9	0.236	9	0.216	8	0.217	10	0.203	11	0.177
Dell Inspiron 2500: Cel 800MHz, 128MB, 10GB, 15TFT, WinME	1646	28	0.613	38	0.718	45	1	3	0.290	3	0.262	3	0.255	7	0.219	2	0.228	2	0.216
IBM ThinkPad A21m (2628G1U)	2000	9	0.637	26	0.729	90	0	10	0.257	10	0.234	10	0.215	10	0.208	12	0.193	10	0.178
IBM ThinkPad A21e (2628CTU)	1639	25	0.613	50	0.709	90	0	5	0.280	6	0.247	6	0.227	11	0.196	14	0.183	6	0.184
Dell Inspiron 2500: P3 1GHz, 128MB, 10GB, 15TFT, Win2000	2096	19	0.625	18	0.737	90	0	27	0.199	16	0.217	13	0.205	12	0.191	9	0.204	12	0.175
IBM ThinkPad A21e (2628JTU)	1984	16	0.628	23	0.732	30	2	20	0.219	13	0.221	15	0.198	14	0.184	17	0.176	18	0.156
IBM ThinkPad A21e (2628JUU)	1976	17	0.626	25	0.729	195	-1	21	0.217	14	0.220	16	0.196	15	0.183	18	0.175	19	0.156
IBM ThinkPad A21m (2628FWU)	2306	7	0.649	15	0.738	45	1	30	0.196	21	0.200	22	0.184	13	0.185	16	0.181	22	0.151
Dell Inspiron 2100: P3 700MHz, 128MB, 10GB, 12.1TFT, Win2000	2074	26	0.613	21	0.734	90	0	36	0.181	18	0.208	18	0.193	17	0.180	11	0.195	17	0.159
Dell Inspiron 2100: P3 700MHz, 128MB, 10GB, 12.1TFT, WinME	1748	36	0.607	32	0.725	90	0	15	0.229	22	0.199	17	0.194	18	0.178	15	0.181	13	0.174
Dell Inspiron 4000: P3 1 GHz, 128MB, 10GB, 14.1TFT, Win2000	2275	18	0.626	11	0.742	195	-1	40	0.155	25	0.188	24	0.179	21	0.171	13	0.186	20	0.152
IBM ThinkPad A21e (2628JCU)	1955	20	0.622	37	0.719	195	-1	19	0.220	17	0.215	20	0.189	19	0.174	23	0.161	21	0.152
IBM ThinkPad A21e (2628JVU)	2087	15	0.629	29	0.727	30	2	28	0.198	19	0.206	23	0.182	22	0.171	21	0.162	25	0.145
IBM ThinkPad A21e (2628JAU)	1857	33	0.609	44	0.713	195	-1	18	0.220	20	0.201	21	0.184	24	0.163	25	0.155	23	0.147
IBM ThinkPad A21e (2628C1U)	1440	66	0.585	64	0.688	90	0	7	0.264	12	0.221	12	0.206	20	0.172	20	0.163	14	0.173

MODEL	Price	AHP		REMBRANDT		ELECTRE		PROM-1		PROM-2		PROM-3		PROM-4		PROM-5		PROM-6	
								Usual Cr		U-Shape Cr		V-Shape Cr		Level Cr		V-shape+indif		Gaussian	
IBM ThinkPad A21e (265571U)	1581	62	0.588	129	0.637	238	-2	8	0.260	15	0.220	14	0.204	16	0.181	22	0.162	16	0.161
IBM ThinkPad A21e (2628JWU)	1969	43	0.602	97	0.655	45	1	31	0.195	28	0.184	27	0.171	23	0.163	24	0.158	27	0.136
IBM ThinkPad A21e (2628C2U)	1538	79	0.577	73	0.678	90	0	17	0.220	27	0.186	26	0.172	30	0.143	34	0.134	24	0.146
IBM ThinkPad A21m (2628DTU)	1889	49	0.596	104	0.652	90	0	25	0.205	26	0.187	28	0.169	26	0.158	26	0.145	33	0.132
IBM ThinkPad A21m (2628E2U)	2036	48	0.596	96	0.655	45	1	38	0.165	32	0.167	33	0.154	29	0.148	27	0.143	38	0.121
IBM ThinkPad A21e (2628CSU)	1540	90	0.573	75	0.676	90	0	26	0.202	29	0.177	30	0.160	35	0.134	39	0.124	26	0.139
IBM ThinkPad A21M (2528GLU)	3046	2	0.660	8	0.757	90	0	62	0.110	54	0.097	59	0.092	46	0.102	54	0.093	69	0.067
IBM ThinkPad A20m (26284TU)	2475	34	0.608	31	0.726	90	0	55	0.124	40	0.130	50	0.111	39	0.122	44	0.109	62	0.078
IBM ThinkPad A21e (265573U)	1679	76	0.578	136	0.632	90	0	16	0.224	24	0.190	25	0.172	27	0.154	32	0.136	29	0.133
IBM ThinkPad A21e (2628J1U)	1759	82	0.577	117	0.642	90	0	24	0.209	30	0.176	29	0.167	28	0.149	28	0.142	31	0.132
Dell Latitude C500: Cel 800MHz, 128MB, 10GB, 14.1TFT, Win2000	2363	37	0.606	98	0.654	238	-2	53	0.125	39	0.136	40	0.130	34	0.135	29	0.141	39	0.111
Toshiba Satellite 1755	1399	42	0.603	103	0.653	195	-1	23	0.209	41	0.128	37	0.139	47	0.100	49	0.099	30	0.133
IBM ThinkPad A21e (2628J2U)	1857	70	0.580	111	0.646	30	2	33	0.188	33	0.165	31	0.157	31	0.142	31	0.137	36	0.123
Dell Latitude C810: P3 1.13GHz, 128MB, 10GB,15TFT, Win2000	2593	24	0.617	90	0.662	90	0	63	0.107	46	0.119	46	0.113	38	0.123	35	0.128	49	0.097
IBM ThinkPad A21e (2628JXU)	1853	68	0.582	128	0.637	195	-1	34	0.185	34	0.161	34	0.153	33	0.139	33	0.135	35	0.124
Toshiba Satellite 2805-S202	1799	22	0.622	77	0.674	30	2	39	0.158	51	0.098	52	0.110	60	0.084	59	0.087	41	0.105
IBM ThinkPad A21m (2628DXU)	1759	74	0.579	135	0.634	90	0	29	0.198	31	0.175	32	0.154	32	0.140	38	0.126	37	0.121
Dell Latitude L400: P3 700MHz, 128MB, 10GB, 12.1TFT, Win2000	2386	41	0.604	113	0.645	45	1	60	0.112	44	0.123	42	0.122	36	0.128	30	0.139	44	0.103
Toshiba Satellite 2800-S202	1799	23	0.618	81	0.670	9	5	41	0.147	59	0.092	55	0.101	66	0.077	64	0.077	48	0.097
Dell Inspiron 4000 (63387-890512)	1299	135	0.545	198	0.591	253	-3	11	0.254	23	0.192	19	0.193	25	0.160	19	0.166	15	0.170
IBM ThinkPad A21m (2628F1U)	2053	69	0.581	119	0.642	238	-2	47	0.135	35	0.147	43	0.122	41	0.120	45	0.108	51	0.091
IBM ThinkPad A21m (2628G7U)	2219	57	0.591	47	0.711	90	0	71	0.088	49	0.110	60	0.092	52	0.092	60	0.087	63	0.077
IBM ThinkPad A21m (2628E1U)	1970	86	0.575	126	0.639	195	-1	42	0.147	37	0.140	41	0.126	40	0.120	42	0.114	46	0.099
Toshiba Satellite 2800-S201 (PS280U-8G5L06)	1132	71	0.579	148	0.624	195	-1	22	0.210	42	0.125	38	0.133	53	0.092	56	0.090	32	0.132
Dell Inspiron 8100: P3 1.13GHz, 128MB, 10GB, Win2000	2983	12	0.636	78	0.673	30	2	68	0.097	68	0.081	65	0.086	54	0.092	53	0.096	66	0.068
Hewlett Packard OmniBook xe3	1399	141	0.543	54	0.702	45	1	49	0.130	43	0.124	44	0.117	49	0.095	55	0.093	40	0.109

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