THE APPLICATION OF DECISION SUPPORT SYSTEMS IN THE ERITREAN PUBLIC SECTOR.

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that I have not previously in its entirety or in part submitted at any university for a degree.

ABSTRACT

The traditional skills required in government—wide local knowledge, sound political judgment and concern for the welfare of people—are still essential in the global information society. But, to be more effective, these skills now have to be supported by the new decision-making techniques of operations research and decision support systems. The capacity of the human mind to handle complex issues is limited. This situation of complexity and incapacity makes the application of operations research techniques and electronic DSS essential for good governance outcomes.

Operations research is a multidisciplinary discipline that requires a team approach to decision making. It is based on systems analysis approach because of its preoccupation with interconnections among parts rather than within the parts themselves. This systems approach allows the optimization of an organization's overall goals, not just those of isolated departments.

Optimization is one of the functions of operations research techniques. Linear programming models are most effective at the operational level of decision making with a single objective where scarce or limited resources must be allocated or used in an optimal manner. At the policy level where there are many uncertainties and conflicting objectives, multiobjective programming is more suitable. On the other hand, dynamic programming is flexible and is particularly applied whenever a sequence of decisions must be made and the goal is to find the combination of decisions that optimizes the overall effectiveness of the entire set of decisions. However, when a problem is too complex to be treated by numerical optimization techniques, simulation is used. That is when the problem either cannot be formulated for optimization, because the formulation is too large, there are too many interactions among the variables, or the problem is stochastic (probabilistic) in nature. Despite the analytical power of operations research, many real-world problems are not amenable to direct analytical solution by known mathematical techniques. Hence, in the absence of exact methods to solutions, we usually resort to heuristics, i.e. finding a good but not necessarily the best solution.

Other problems encountered by public sector agencies include service stations (waiting lines), inventory levels, forecasting, and project scheduling, which all need decision support systems. To reduce the adverse impact of waiting to acceptable levels one has to minimize

costs associated with providing service and those associated with waiting time. For smooth operations, inventory of goods must be kept to an acceptable level to minimize setup or ordering, inventory holding, and shortage (public complaints, and loss of good will and sales) costs. Forecasting is crucial as most managerial decisions are based on projected information and policy analysis is almost always about future outcomes. Many government policies and programs are implemented through projects. Project managers must know how long a specific project will take to finish, what the critical tasks are, and what the probability of completing the project within a given time span is.

Successful applications of operations research and decision support systems in the public sector have been recorded including in the areas of the military, transportation, crime and justice, police units, energy, natural resources, facility location, and land use planning. However, operations research applications are not without impediments. Technical and institutional barriers are some of the problems encountered in the effort to apply operations research in the public sector. Similarly, reasons for the slow growth of decision support systems include lack of user demand, lack of system designer motivation, lack of system designer expertise, reluctance to change, and increased risk of failure

In the Eritrean public sector, the low level of awareness of operations research and decision support systems is reflected in the inadequacy of addressing multicriteria decision processes, the lack and /or inappropriate selection of decision support systems, improper project management techniques, suboptimal facility locations and service stations, the low level of multidisciplinary approach, and the absence of national standards for pollution control. In general, constraints such as the lack of capacity, awareness, know-how, and software, are rampant.

The study concludes that policy-making processes should incorporate opportunities to exercise choices and explore rational options. These rational options are the results of appropriate interface of human, operations research and decision support systems.

OPSOMMING

Die tradisionele vaardighede wat van 'n regering verwag word - wye kennis van plaaslike omstandighede, goeie politieke oordeel en besorgdheid oor die welvaart van mense - was nog altyd belangrik in die moderne wêreld. Hierdie vaardighede moet egter ondersteun word deur die nuwe besluitnemingstegnieke van operasionele navorsing en besluitnemings ondersteuningstelsels om effektief te wees. Die vermoë van die menslike brein om komplekse kwessies te hanteer, is beperk. Hierdie situasie van kompleksheid aan die een kant en onvermoë aan die ander kant maak die aanwending van operasionele navorsings-tegnieke en elektroniese besluitneming nodig vir goeie regeringsuitkomste.

Operasionele navorsing is 'n multidisiplinêre disipline wat 'n spanbenadering tot besluitneming benodig. Dit is baseer op die sisteemanalise benadering omdat dit gaan oor interkonneksies tussen onderdele en nie soseer oor die onderdele self nie. Hierdie sisteembenadering maak die optimisering van die sisteem se oorhoofse doelwitte moontlik, nie net die doelwitte van geïsoleerde departemente nie

Optimisasie is een van die funksies van operasionele navorsing. Liniêre programmerings-modelle is meer effektief op die operasionele vlak van besluitneming met 'n enkel doelwit waar skaars of beperkte bronne toegewys of gebruik moet word op 'n optimale wyse. Op die beleidsvlak waar baie onsekerhede en botsende doelwitte voorkom, is multi-doelwit programmering meer geskik. Aan die ander kant is dinamiese programmering meer toepaslik en buigsaam, veral as dit toegepas word waar 'n reeks besluite geneem moet word en die doel is om 'n kombinasie van besluite te vind wat die oorhoofse effektiwiteit van die hele stel besluite optimiseer. Sekere probleme is egter te kompleks om met numeriese optimisering op te los, omdat die probleem nie geprogrammeer kan word vir optimisering nie, omdat die formulasie te groot is, daar te veel interaksies tussen die veranderlikes is, of die probleem stogasties van aard is. Dan kan simulasies oorweeg word om oplossings te probeer vind. Ten spyte van die analitiese krag van operasionele navorsing, kan baie werklike probleme nie direk deur analitiese wiskundige tegnieke opgelos word nie - altans nie deur bekende wiskundige tegnieke nie. As 'n presiese oplossing nie moontlik is nie, kan kan 'n heuristiese oplossing ondersoek word, d.w.s. 'n goeie, maar nie noodwendig die beste oplossing nie.

Ander probleme wat deur die openbare sektor ondervind word, sluit in diensstasies, inventarisvlakke, voorspellings, en projekskedulering. Hulle benodig almal besluitnemingsstelsels vir effektiewe oplossings. Om die wagtydperk te verminder tot 'n aanvaarbare vlak moet die koste verbonde aan die verskaffing van die diens en die koste verbonde aan wagtydperke minimiseer word. Om 'n operasie glad te laat verloop moet die inventaris van goedere op 'n aanvaarbare vlak gehou word om die koste van bestellings, die byhou van voorrade en tekorte (klagtes van die publiek, die verlies aan vertroue en verkope) te minimiseer. Voorspelling is van die uiterste belang vir hierdie doel, omdat bestuursbesluite baseer is op geskatte syfers en beleidsontleding betrekking het op toekomstige uitkomste. Baie regeringsbeleide en -programme word deur projekte geïmplementeer. Projekbestuurders moet weet hoe lank dit sal neem om 'n projek te voltooi, wat die belangrike take is en hoe waarskynlik dit is dat die projek betyds voltooi sal word.

Operasionele navorsing en besluitnemingsondersteuning stelsels is al suksesvol aangewend in die volgende openbare sektore: militêre funksies, vervoer, misdaad en justisie, die polisie, energie, natuurlike hulpbronne, en die beplanning van grondgebruik. Tegniese en ander hindernisse word egter soms ondervind by die gebruik van operasionele navorsingstegnieke in die openbare sektor. Redes hoekom die gebruik van sulke stelsels so stadig toeneem, sluit in die gebrek aan aanvraag van verbruikers, die gebrek aan stelselontwerp motivering, die gebrek aan stelsel ontwerp vaardighede, onwilligheid om te verander en die groter risiko van mislukking.

In die openbare sektor van Eritrea word die lae vlak van bewustheid van operasionele navorsing en besluitnemingsondersteuning stelsels gereflekteer in 'n onvermoë om dit te gebruik, die gebrek aan of verkeerde keuse van sulke hulpmiddels, verkeerde bestuurstegnieke, suboptimale plasing van dienspunte, die afwesigheid van multi-disiplinêre benaderings, en die afwesigheid van nasionale standaarde vir die beheer van besoedeling. Beperkings soos 'n gebrek aan kapasiteit, bewustheid, kennis en sagteware kom algemeen voor.

In hierdie studie word daar tot die gevolgtrekking gekom dat beleidmakende prosesse die geleentheid behoort in te sluit om keuses te maak en om verskillende opsies te toets. Hierdie rasionele opsies is die gevolg van die regte interaksie tussen die mens, operasionele navorsing en besluitnemingsondersteuning stelsels.

This thesis is dedicate to:

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ABBREVIATIONS

CPM—critical path method

CPUE—catch per unit effort

DSS — decision support systems

GDSS—group decision support system/s

GIS—geographic information systems

ICT — information and communication technologies

MIS — management information systems

MOLP—multiple objective linear programming

MSY—maximum sustainable yield

OR — operations research

PERT—program evaluation and review technique

HTML—hypertext markup language

EOQ—economic order quantity

GLOSSARY

Algorithm: a step by step procedure where each step is described so precisely that it can be set up for execution by a computer, that leads unambiguously from one step to the next, until in a finite number of steps it terminates with an optimum solution of the model if one exists (Murty, 1995:2).

Bandwidth: Bandwidth has a general meaning of how much information can be carried in a given time period (usually a second) over a wired or wireless communications link. More technically, bandwidth is the width of the range of frequencies that an electronic signal occupies on a given transmission medium. Any digital or analog signal has a bandwidth (SearchNetworking.com, 2004).

Constraints: mathematical expressions that state resource limitations or other physical restrictions in a particular decision model (Cook & Russell, 1989:803).

Critical activities: activities in a PERT network that are on the critical path and consequently have zero slack time (Cook & Russell, 1989:803).

Critical path method (CPM) the longest path from the origin node to the terminal node. This gives the excepted project duration (Nicholas, 2001:205). A project network analysis technique used to predict total project duration (Murty, 1995:2).

Critical path: the longest path through a PERT network. The critical path is composed of activities with zero slack time (Cook & Russell, 1989:803).

Critical path: the series of activities in a project network diagram that determines the earliest completion of the project. It is the longest path through the network diagram and has the least amount of slack or float (Murty, 1995:2).

Decision support systems: computer based information system that combines models and data in a attempt to solve nonstructured problems with extensive user involvement through a friendly user interface (Turban & Aronson, 2001:809).

Decision-making: the action of selecting among alternatives (Turban & Aronson, 2001:809).

Delphi method: a qualitative forecasting methodology using anonymous questionnaires effective for technological forecasting and for forecasting involving sensitive issues (Turban & Aronson, 2001:809).

Deterministic: a mathematical model in which all its parameter values are assumed to be known with certainty (Rardin, 1998:16).

Dynamic programming: a serial optimization method that decomposes a problem into smaller interrelated problems in order to find the overall optimum solution (Cook & Russell, 1989:803).

EOQ: it is a nonlinear optimization problem used to determine the optimal quantity of a product to purchase whenever an order is placed (Ragsdale (2001:342).

GRG (***generalized reduced gradient***): the solution procedure Solver uses to solve NLP problems (Ragsdale (2001:338).

Goal programming: a mathematical programming technique that solves optimization problems having multiple and sometimes incompatible goals. It is concerned with the achievement of prespecified goals or targets (Cook & Russell, 1989:32, 804). The constraints are soft or flexible (Ragsdale (2001:298)

Group support systems: information systems that support the work of groups (communication, decision-making) generally working on unstructured or semistructured problems (Turban & Aronson, 2001:812).

Groupthink: in a meeting continual reinforcement of an idea by group members (Turban & Aronson, 2001:812

Hard constraints: constraints that cannot be violated.

Heuristics: a rule-of- thumb for making decisions that might work well in some instances, but not guaranteed to produce optimal solutions or decisions (Ragsdale, 2001:77). A simple decision rule of thumb formed by individuals, which provide simple guidelines for classifying and interpreting data and which can take the form of simple decision rules (Jennings & Wattam, 1998:81).

HTML: HTML (Hypertext Markup Language) is the set of markup symbols or codes inserted in a file intended for display on a World Wide Web browser page. The markup tells the Web browser how to display a Web page's words and images for the user (SearchNetworking.com, 2004).

Iterative technique: in a solution process that repeats certain phases of the situation process until a solution is found (Cook & Russell, 1989:804).

Linear programming: a mathematical technique that can be used to maximize or minimize a linear objective function subject to certain linear constraints. It is a component of mathematical programming. (Cook & Russell, 1989:32, 804).

Mathematical programming: is a field of management science (operations research) that finds the optimal, or most efficient, way of using limited resources to achieve the objectives of an individual or a business (Ragsdale, 2001:16).

Model: the area of concern or domain mimicked or copied to extract essentials of behavior, size, characteristics, and hence study the model rather than actuality directly. The model can thus be an exact or scaled replica of the area of concern/domain (Jennings & Wattam, 1998:816).

Multiple objective linear programming: a linear programming model with more than one objective function (Cook & Russell, 1989:803).

Optimal solution: a solution that is not only feasible, but also achieves the best possible value for e objective function.

Optimization: the process of identifying a best possible solution to a problem (Turban & Aronson, 2001:816).

PERT —program evaluation and review technique—is a way to warn managers of the need to compensate for the consequence of a risk on project duration. It incorporates risk into project schedules by using three estimates from each project activity: optimistic, most likely, and pessimistic times (Nicholas, 2001:213).

Project scheduling: the scheduling of major tasks that require a significant amount of time to accomplish (Cook & Russell, 1989:806).

Rationality: a concept concerned with logical and systematic processing of data which are seen to be objective in nature (Jennings & Wattam, 1998:82).

Sensitivity analysis: the analysis of how an optimal solution and the value of its objective function are affected by changes in the various inputs or parameters of the decision model (Cook & Russell, 1989:806).

Slack time: in PERT analysis, the amount of time an activity can be delayed without delaying the entire project (Cook & Russell, 1989:807).

Soft constraints: are those that specify requirements that are desirable to satisfy but which may still be violated in feasible solutions.

Stochastic *or* ***probabilistic***: are those in which the data are not known with certainty, but a probability distribution is known (Cook & Russell, 1989:24).

Systems approach: a modern integrated approach to decision-making in which all relevant factors including intra-organizational or external factors) are considered in the decision process. The objective is to achieve the goals of the organization as a whole (Cook & Russell, 1989:807).

Uncertain problems: problems with uncertain data (Cook & Russell, 1989:24).

What-if-analysis: asking a computer what the effect fo changing some of the input data or parameters will be (Turban & Aronson, 2001:809).

Work package: a deliverable or product at ht lowest level of the work breakdown structure (Schwalbe, 2000:480).

Chapter I

General Introduction

1.1. Introduction

Johnson (1999) describes the role of operations research (OR) in policy formulation in the public sector as follows:

> In the public sector, operations research is uniquely positioned to help decision-makers solve problems with multiple stakeholders, multiple objectives, multiple alternative actions and policy restrictions on allowable actions. Whereas economics may provide insight to decision makers regarding properties of certain given policies, and management information systems may assist micro-level implementation of given policies, operations research can help decision-makers determine exactly what policy to pursue and the estimated impacts associated with alternative policies.

Operations research aims to provide rational bases for decision making by seeking to understand and structure complex situations and to use this understanding to predict system behavior and improve system performance. OR plays an increasingly important role in both the public and private sectors. In the public domain, it deals with such topics as energy policy, defense, health care, water resource planning, forestry management, design and operation of urban emergency systems and criminal justice. An organization that has decided to improve its planning or its operations by leveraging OR techniques needs to make a choice on the design and implementation of information technology to perform this task

According to Foulds and Thachenkary (2001), the recent explosion of this information technology has made the practice of OR much more widespread than in previous decades. In the past, in order to address complex problems arising in government and industry, many OR practitioners relied on constructing large-scale models and attempted to solve them using optimization techniques such as mathematical programming. A growing body of opinion questions whether such an approach, on its own, can deal successfully with many of the complex, ill-defined, difficult-to-model issues now facing OR practitioners. This has given rise to other approaches, such as soft systems methodology, to tackle what Ackoff termed today's 'messes' that most government problems are (Foulds & Thachenkary, 2001).

OR has been used intensively in business, industry and government. Many new analytical methods have evolved, such as: mathematical programming, simulation, game theory, queuing theory, network analysis, decision analysis, multicriteria analysis, which have powerful application to practical problems with the appropriate logical structure. Most of the problems OR tackles are messy and complex, often entailing considerable uncertainty. OR can use advanced quantitative methods, modeling, problem structuring, simulation and other analytical techniques to examine assumptions, facilitate an in-depth understanding and decide on practical action (EURO, 2003). The 1990s brought about a renaissance of OR fuelled by the ubiquitous personal computer and powerful desktop software and many other user-friendly tools for implementing management science theories.

Pinkus and Dixson (1981:1) observe that businesses, all over the world are influencing government practices for more productivity. It is not surprising to find that government practitioners are increasingly using the same techniques for management that have been the domain of businesses for some time. The traditional skills required in government—wide local knowledge, sound political judgment and concern for the welfare of people—are still essential. But, to be more effective, these skills now have to be charged with a battery of new techniques like those used in industry or commerce. Terms such as cost-benefit analysis, discounted cash flow and cost effectiveness have become common currency at council meetings, at legislative sessions and in departments at all levels of government.

However, the infiltration of OR to the public sector has not been easy and has traveled a tortuous road. According to Byrd (1975:6), OR has only recently become more prominent in the management of governmental programs. The reasons for this are many, but two are predominant. First, governmental programs are generally administered by persons who do not have strong analytical backgrounds. Their expertise lies in their ability to take loosely structured problems and to abstract from them qualitative factors, which they use in making decisions. The OR professional on the other hand, has a strong analytical background and is quite adept in applying his knowledge to well structured problems. But as problems become less well structured, the OR professional has been less effective at incorporating qualitative factors into his decision making model.

Moreover, in order to meet the required public demand effectively and efficiently, and to realize their full potential, OR techniques need to be aided by electronic decision support tools. These tools even go beyond the capabilities of the techniques. Cook and Russell (1989:700) show that decision support systems (DSS) extend OR by dealing with problems that do not have enough structure to be 'solved completely' by any particular OR model. Similarly, The capacity of the human mind to handle complex issues that are modeled by OR techniques is limited. This situation of incapacity necessitates the use of decision support tools without which the OR models themselves are more or less of no use. OR and DSS can be seen as complementary, hence the title of this paper.

1.2. Eritrean Context

Due to its colonial history the Eritrean economy has been neglected, and its technologies have lagged far behind that of many developing countries and it has been difficult to catch up in its short period of independence (1991). One way of expediting human and economic development is the formulation of feasible policies, strategies, and programs that serve as frameworks for the efficient and effective operations of projects and other activities. These operations are dependent on the style of decisions and the technology employed. Given its low financial, material, and human resources, Eritrea should be a high consumer of OR and DSS, because they save costs by optimizing usage of resources. With its limited human and material resources it requires a scientific decision-making approach to manage its resources efficiently, and OR and DSS are the techniques and tools that are aiming at improving the quality of decisions for managing scarce and valuable resources. Such resources include not only financial resources but also issues related to the quality of human life, medical treatment, the environment and many other important issues. In general, there is a converging consensus that the advantages of OR and DSS can be combined to offset the weaknesses of the economy and improve quality of life.

Eritrea is situated in the volatile and turbulent region of the Horn of Africa where many geo-political and economic forces interact rapidly and nonlinearly that increase the complexity of decision-making processes. The relationship with the neighboring states fluctuates from active cooperation to acute hostility and bloodshed. The instability of the region will mean that decisions will not have predictable consequences and there must be mechanisms in place to cope with instability. If we accept the perspective of chaos theory then a radically different approach to decision-making is required. Old assumptions must be discarded and replaced with methods and attitudes, which can cope with the realities of chaos rather than control and manage stability (Jennings & Wattam, 1998:323). To find its way in the multitude of issues in a rapidly changing and complex environment decisions should be supported by technology.

The theoretical base of OR and DSS in Eritrea is not strong enough to be applied in the work environment. They have not yet infiltrated into the public or into the private sector. In the University of Asmara, the only university in Eritrea, OR is taught as part of the management courses and not as a separate discipline.

1.3. Problem Statement and Research Objectives

Policy problems have most of the characteristics of complex and ill-structured problems. Funke (as cited in Fernandes & Simon, 1999: 225-226) has defined complex problems as having the following features:

a) *Intransparency*: only knowledge about the symptom is available, only some variables lend themselves to direct observation, or, the large number of variables require selection by the problem solver of a few relevant ones,
b) *Polytely*: multiple goals may be present that could interfere with each other,
c) *Situational complexity*: there are complex connectivity patterns between variables; and
d) *Time-delayed* effects: not every action shows immediate consequences.

The environments in which problems exist and decisions made are not the same and therefore call for different methods of treatment. Cook and Russell (1989:24) indicate that OR procedures fall into one of three categories. These three categories are defined according to the nature of the environment in which a decision must be made. The environment or the data for a problem, as identified by Cook and Russel, can be one of the following:

- Deterministic problems
- Stochastic problems
- Uncertain problems

Depending on the skill levels and experience, there are many ways in which managers can deal with problems. According to Cook and Russell (1989:2), management can approach complex decision problems in several ways. Managers may resort to intuitive or observational approaches that depend on subjective analysis. Or, putting faith in 'proven' procedures, they may simply repeat other managers' solutions. Such attempts at handling problems are sometimes called seat-of-the-pants approaches. They may not attack the problems in a systematic manner, and they do little to improve or advance the managerial decision process. On the other hand, an OR approach provides a rational, systematic way to handle decision problems. Using a systematic approach, the decision maker has a better chance to make a proper decision.

These decisions made in the public sector impact on our lives, regardless of where we live. Hence, we all have an interest, one way or another, in the achievement of efficiency and productivity improvements in the activities of the public sector. For a government agency that provides a public service, striving for unreasonable benchmark targets for efficiency may lead to a deterioration of service quality, along with an increase in stress and job dissatisfaction for public sector employees. Slack performance targets may lead to gross inefficiency, poor quality of service and low self-esteem for employees. In the case of regulation, inappropriate policies can lead to unprecedented disasters.

As indicated above, decision for policy-making is a high-risk activity in the sense that it has a large probability of failure. It is also difficult, as public sector problems usually do not have a definitive, singular formation. They are multiobjective, and require careful planning and management policy-making. The diverse Eritrean society is becoming ever more complex with vast developmental activities and worldwide economic and diplomatic networks. The resources of the country are very limited and have to be managed in an efficient manner. Hence, as the complexity of problems grow, more rigorous and systematic research in public administration is needed.

Despite all these complexities, many administrators have fallen under the illusion that decision-making in practical situations does not require any serious mathematical analysis and modeling and should be exclusively based on practical experience. However, practical experience alone has a limited scope and cannot solve complex societal problems that need a scientific methodology like OR. Nonetheless, real OR does not come neatly packaged and ready for mathematical analysis. Since human affairs are dominated not by technical considerations but by culture, personalities, and politics, OR techniques cannot be applied blindly. They need to be incorporated with human beings' judgment and intuition.

In the Eritrean public sector OR approaches to decision-making is hardly in practice and the support of electronic tools is still in its infant stage. This deficiency of these scientific methods is reflected in:

- Suboptimal location of facilities, which may result in the loss of human life, inordinate transportation cost, public complaints, and environmental degradation;
- Decisions which are not sufficiently multidisciplinary and systems view, which may result in partial solution and lack of coordination; and
- Unjustifiable and irrelevant work, which may result in inefficiency, delays, costs, and subjectivity.

The application of OR and electronic DSS will be assessed in the Ministry of Land, Water and Environment; the Ministry of Education; the Ministry of Health; the Ministry of Agriculture; the Ministry of Fisheries; the Commercial Bank of Eritrea.; and the Grain Board.

The basic premise here is that since there is a growing trend of OR applications worldwide, specially with the advent of modern computers that demystified the once seemingly intractable models, Eritrea can benefit by adopting these technologies. The application of OR techniques coupled with DSS can result in more efficient, effective, and transparent use of all its scarce resources.

The objectives of this study are to identify the practices of the selected public sector organizations in which OR techniques and decision technology tools can be applicable and propose the most user-friendly and easily available electronic tools. These techniques and tools are aimed at enhancing efficiency, effectiveness and transparency in the public sector. Hence, the salient objectives of the research are:

- To assess the status of OR and decision support tools in the selected Eritrean public sector organizations;
- To indicate that OR and DSS enhance the decision-making capabilities of administrators for effective and efficient use of scarce resources;
- To create awareness of the potential of OR techniques and electronic decision tools and demonstrate their applicability in the Eritrean public sector;
- To illustrate more scientific decision-making, using qualitative and quantitative approaches; and
- To enhance transparency of decision processes, avoid wastage of resources, and to create awareness of communication technologies for better informed decisions and dissemination of information.

In general this thesis aims at serving as an entry point of OR to the Eritrean public sector by creating awareness of the need for change (unfreezing).

1.4. Research Design and Methods

The research approach followed in this paper is qualitative. According to Gabriellian (1999:190-191), qualitative research employs a host of techniques for collecting and analyzing data. As Punch (cited in Gabriellian, 1999:190-191) observes, three are central—observation, interviewing, and documentary analysis—that may be employed across a variety of disciplines. In the practical aspect, interviews with heads of organizations and observations were the main techniques used in the data collection process. The researcher conducted in-depth interviews with the relevant officials to understand and explore the methods of work of the organizations. The types of research questions are exploratory and predictive, intended to investigate the phenomena, identify important variables, and predict the outcomes of the phenomena. In addition, some secondary data of the organizations were referred as a supplementary to the interviews.

This paper reviews literature regarding the potential and current application of OR and DSS in the Eritrean public sector in general, and assesses some of the public sector organizations in light of the literature in particular. The content of this study is mainly a literature review with the aim to explore and understand the operations of the public sector and to recommend better ways of decision-making. This can be accomplished by adopting OR techniques and the help of electronic decision tools whose practicality and superiority to traditional methods is widely supported by the literature. In addition, it briefly discusses some of the visited public sector organizations regarding their potential application of OR techniques and DSS.

Basically, this paper is a recommendational study in order to familiarize the public sector with new techniques of decision-making and electronic tools that support them. The electronic tools that are demonstrated in Chapter IV are selected on the basis of their user-friendliness, availability, familiarity, and cost.

1.5. Limitations

None of the visited sectors are applying OR and do not have significant DSS of any kind. So it has been very difficult to evaluate in terms of these techniques and tools. In which areas has OR or DSS been successful or failed is impossible to determine. Even during the interview, because the concepts were new to many officials, communication has not been easy and it was difficult to elicit the desired information. On the other hand, because of the time and financial limitations, it was not possible to visit all the intended organizations in general and in South Africa in particular.

Most of the literature in our library regarding OR and DSS was written in relation to business. Thus relevant reference materials were not easily available, and the researcher was obliged to extrapolate the business techniques to the public sector. Similarly, no prior research of this kind has been done (at least which is known to the researcher) in Eritrea that can be used as a starting point or reference.

1.6. Organization of the Study

The paper is organized in five chapters. Following this introduction, in Chapter II, OR's scientific approach to decision-making, its essential characteristics, its functional relationships from a systems overview, its role in policy analysis, its multidisciplinary nature, and the advantages of models are discussed. It further discusses OR's role in solving optimization and multiple objective problems, and project scheduling through various modeling techniques. It also deals with simulation, forecasting, inventory, and queuing models. As all problems are not amenable to exact scientific methods (that guarantee optimum solution) there will be a need to resort to heuristics and this is discussed in the subsequent section. Finally, after citing successful areas of OR application in the public sector, the chapter will conclude by presenting some impediments to the discipline.

In Chapter III, the nature of DSS is presented. Here, after discussing the nature of DSS, it is shown that the application of OR techniques is dependent on the electronic DSS. It is also indicated that the support given to decision-making is not limited to individuals but includes groups, and hence the development of group DSS. Then, the characteristics of DSS and the challenges they face from users and complexity theories, the role of communication technologies, the Internet, and Geographic Information Systems (GIS) are discussed. Some user-friendly DSS, which can be easily affordable in terms of money, are also proposed—given the level of development of Eritrea.

Chapter IV, after a brief introduction to Eritrea, is devoted to limited empirical aspects of the study in which different organizations are evaluated in terms of some aspects of OR and DSS. From the list of software mentioned in Chapter III, the application of spreadsheet add-ins (Premium Solver, and What's*B*est), and V.I.S A. have been demonstrated in the Ministry of Land, Water, and Environment, the Ministry of Health and the Ministry of Fisheries. Here, the applications for multidisciplinarity, facility location, and multiobjective problems are shown. Finally, in Chapter V, the paper ends by drawing conclusions and giving recommendations relevant to the Eritrean public sector.

Chapter II

Decision-making

and Policy Analysis

2.1. Introduction

Even though the history of OR as a discipline goes back to the Second World War, until the advent of modern computers it was considered too abstract to apply in the public sector. However, since the 1980s OR has witnessed its positive contribution to sound policy formulation, which ultimately leads to the efficient and effective use of public resources.

As an introductory section to the whole study, the subsections that follow discuss the nature of decision-making, which include the components of decision-making and decision variables, categories of decision-making, structured and unstructured decision processes, classes of decision makers, errors in the decision-making process, and human beings-models interface, which stresses that the ultimate decision-maker is man and not models.

In the subsequent sections of this chapter, the characteristics of OR followed by the art and science of OR will be discussed. In the art and science part, the scientific approach to problem solving as a process of different phases will also be dealt with. OR is mostly characterized by its mathematical orientation, which is known as hard OR. Moreover, to have a wider scope, a brief description is given to introduce what soft OR is as opposed to hard OR.

Operations research is very much related to systems and policy analysis and this is given due consideration in the sections to follow. In addition a significant attention has been given to the part, which shows the multidisciplinarity approach.

Modeling is an important ingredient for decision and insight and this chapter gives much space to this discussion. Optimization models like linear programming, dynamic programming, goal programming, and other techniques such as simulation, forecasting, queuing, and inventory models are also the topics to be discussed in some detail. As a field of OR, project management is also another area dealt within this chapter. Despite all the scientific discoveries and development of various discoveries, many real-world problems are not amenable to known mathematical techniques, in which case we are forced to resort to heuristics, which is the subject of this chapter as well.

The application of OR in the public sector is so vast that this paper cannot exhaust it fully. Nevertheless, towards the end the areas of the military, transportation, crime and justice, police units, energy, natural resources, facility location, and land use planning will be cited as some successful applications of OR. In addition, the application of OR and DSS in some selected countries will be presented. Finally, the chapter will conclude by presenting some impediments to OR.

2.1.1. The Nature of Decision-Making

> The work of managers, of policy makers, of scientists, of engineers, of lawyers—the work that steers the course of society and its economic and governmental organizations—is largely work of making decisions and solving problems. It is work of choosing issues that require attention, setting goals, finding or designing suitable courses of action, and evaluating and choosing among alternative actions. The first three of these activities--fixing agendas, setting goals, and designing actions--are usually called problem solving; the last, evaluating and choosing, is usually called decision-making (Simon et al., 1986).

Furthermore, according to Stevens and Thompson (1996), decision-making can be defined as the process of making a choice between alternatives. The components of this process are: data, decision models, the decision environment and people (Figure II-1). Each of these components has a direct influence on which alternative gets chosen.

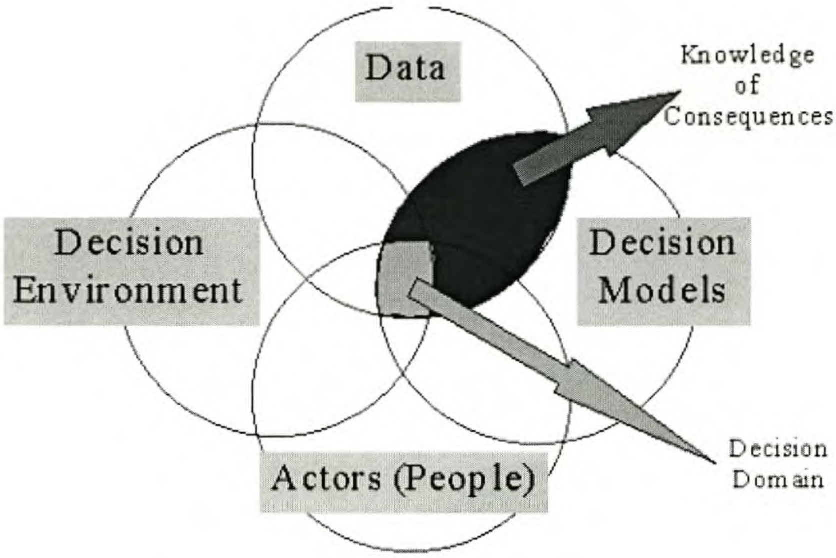


Figure II-1. The four components of decision-making.

Source: Stevens and Thompson (1996).

According to Jennings and Wattam (1998:2), the need to improve decision-making arises because:

- In general, organizations face a scarcity of resources and the need to make the most effective use of those that are available to them;
- Increasingly both private and public sector organizations face competition, either from the rising pace of competition or through government exposing more organizations and their decisions to market disciplines; and
- Issues such as consumer safety, pollution and employment practices frequently raise public concern over the degree of social responsibility demonstrated by organizations in their decision-making. Both public and private sector organizations often find themselves open to examination by the wider society, not only for the results of decisions they have made, but also for how those decisions were arrived at.

As Pinkus & Dixson (1981:2) put it, OR is particularly applicable to problems of decision-making where many interacting considerations are involved, and where more than one solution is feasible. In these cases the analytical processes that constitute the OR method can help find the best course of action where intuitive method might not. Looked at it in this way, it can be seen that OR is ideally suited to the kind of complex problems encountered daily by government.

Decisions, which involve complex factors, are difficult to evaluate in a uniform and consistent way. It is a characteristic of such decisions that they have to be made in a transparently justifiable way and not on the basis of some capricious whim. The importance of transparency being that it allows it to be seen, by all interested parties, that all the relevant technical, economic and moral issues have been considered (Chicken & Hayns, 1989:4). They further state that decision-making is not a uniform practice, which implies that attention must be drawn to the fact that with the passage of time the need for a decision may either increase or decrease, and requirements of knowledge and resources may vary (see Table II-1)

Decision variable	**Changes that may occur with the passage of time**
Knowledge	Improved knowledge may show that an action is no longer required or must be modified
Resource requirement	Demand for resources in terms of material, finance or manpower may be different to originally predicted
Requirement for decision	Demand for decision and action may increase or decrease

Table II-1. Summary of changes possible with time in the decision-making environment.

Source: Chicken and Hayns (1989:5).

Likewise, to match to the complexity of factors changes have also been made to the decision aid tools. According to Belenky (1998:1-2), the development of personal computers, along with that of computer graphics, has created premises for eclipsing mathematical methods of optimization as the tool for decision-making in planning and control by interactive and expert systems. Such systems actively incorporate the user in the decision-making process, but they do not guarantee, in fact, either finding optimal or rational decisions. At the end the decision maker is the human being. When considering the nature of decision-making, decision-making processes and decision makers need further clarification.

2.1.1.1. Categories of Decision-Making Processes

Taha (1997:519) states that decision analysis involves the use of a rational process for selecting the best of several alternatives. The 'goodness' of a selected alternative depends on the quality of the data used in describing the decision situation. From this standpoint, a decision-making process can fall into one of three categories.

a) Decision-making under *certainty* in which the data are known deterministically;
b) Decision-making under *risk* in which the data can be described by probability distributions; and
c) Decision-making under *uncertainty* in which the data cannot be assigned relative weights that represent their degree of relativity in the decision process.

The emphasis of uncertainty in the mode of decision-making process is referred to by Caulkins (2002) who states that the first lesson for practicing policy analysis is that all models should consider incorporating uncertainty. The risk in articulating this lesson is the temptation to respond by discarding models altogether rather than by making them stochastic. But closing one's eyes when it's foggy does not improve one's driving. Instead of moving blindly we should be able to identify the probabilities involved in the situation.

2.1.1.2. Structured and Unstructured Decision Processes

According to Bonczek, Holsapple, and Whinston (1981:14), decision-making processes fall along a continuum that ranges from highly structured to highly unstructured. These two end points are sometimes referred to as programmed and nonprogrammed, respectively. The former refers to decision-making that is routine and repetitive. The latter is descriptive and refers to situations where there is no cut-and-dried method of handling the problem because it hasn't arisen before, or because its precise nature and structure are elusive or complex, or because it is so important that it deserves custom- tailored treatment.

2.1.1.3. Classes of Decision Makers

There are many types of decision makers that must be supported, and hence many types of DSS. According to Marakas (1998:39-42), the classes of decision makers are:

a) Individual

The individual decision maker works alone during the decision process in the sense that the analysis of information and the ultimate generation of a final decision rests solely in his/her hands. A decision support system intended for use by an individual problem solver must be designed to cater for his or her unique characteristics and needs.

b) Multiple

This class of decision makers is made up of multiple individuals interacting to reach a decision. Each member of this class may have unique motivations or goals and may approach the decision process from a different angle. Multiple decision makers do not possess equal authority to make a particular decision, nor do any of them possess enough authority to make the decision alone. Multiple decision makers do not necessarily meet in a formalized manner or conduct open forums or discussions as a unit. Instead, the institutionalized patterns of communication and the various levels of authority within the organization structure the interaction among the participants in such a way that eventually a decision is reached. Each may use a common DSS in a variety of systems as support for his or her contribution to the decision-making process.

c) Group

A group decision maker is characterized by membership in a more formal structure where each member of the group has a similar vested interest in the decision outcome and has an equal say in its formation. Group decision makers generally work in a formal environment that consists of regular meetings devoted to working through the decision process, formal schedules and agendas focusing on specific portions of the process and often deadlines by which the decision must be finalized and operationalized.

Group decision-making is becoming more and more important. In governmental policy making there has been a shift from decision-making by a strong actor to a more undefinable negotiation process with many partners in which individual decisions can barely be identified (Kenis, 1995:10).

d) Team

Team is a combination of the individual and group classes. In the team context, decision support may come from several individuals empowered by the key individual decision maker to collect information and/or make certain determinations regarding a portion of the intended decision outcome.

e) Organizational and Metaorganizational

Organizational level of decision makers are embodied by the most senior level of management: the CEO, which needs a special type of DSS called Executive Information Systems. Decisions by this class require support from the entire organization if they are to be successfully implemented.

On the other hand decision makers operating at the metaorganizational level tend to be oriented toward social welfare, quality of life, allocation of controlled or limited resources, social order or civil justice. Hence they require a special support system.

2.1.1.4. Errors in Decision-Making

a) Individual Errors

Since decisions in the public policy arena have the largest potential to affect many people, they have to be based on informed and scientific methods. If policy decisions are defective, the consequences of the errors are enormous.

Many errors resulting from bad decision-making plague many public sector institutions. These errors may originate from various aspects some of which are identified by Sawyer. Sawyer (as cited in Turban & Aronson, 2001:56) describes the "Seven deadly sins of decision-making," most of which are behavior or information related. They are:

- Believing that you already have all the answers;
- Asking the wrong question;
- The old demon ego (a decision maker feels he or she is right and refuses to back down from a bad policy or decision);
- Flying-by-the-seat-of-your-pants saves money—(by not seeking information, an organization saves money—and makes bad decisions);
- All aboard the bandwagon: if it works for them, it works for us;
- Hear no evil (discourage and ignore negative advice—kill the messenger with the bad news); and
- Hurry up and wait: making no decision can be the same as making a bad decision.

b) Group Errors

There are many dysfunctional issues in face-to-face meetings including speedy decisions, central tendency, groupthink, risky shift, and hidden agenda (see section 3.3).

2.1.1.5. Human--beings–models Interface

Decision analysis by definition entails the exposition of formal models. These are, of course, technical instruments to aid decision-making. But models do not make decisions by themselves. People do that. The modeler helps people besides himself or herself to use the models. These potential users ideally might include those who claim ultimate authority, or at least influence, over the decisions. Citizens, stakeholders, clients, policymakers, technical critics—all can get into the game, provided the models are built right (Bardach, 2002:486).

Cook and Russell (1989:15) assert that no model is perfect, and no model can truly represent the situation it symbolizes. Thus, successful management science projects do not depend solely upon models and scientific techniques. As the discipline becomes more sophisticated, greater emphasis is being placed on human factors. There is awareness of the need to balance purely quantitative approaches with the experience, judgment, and insight provided by management.

2.1.1.6. Decision Support (Making) Disciplines

According to Bohanec, decision-making encompasses a number of more specialized disciplines among which the most important are: OR, DSS, group decision support systems, decision analysis, and data warehousing. This paper will be limited to OR and DSS. Group support systems will be discussed alongside DSS.

Bohanec's view of OR and DSS is as follows:

a) Operations Research

Operations Research is concerned with optimal decision-making in, and modeling of, deterministic and probabilistic systems that originate from real life. These applications, which occur in government, business, engineering, economics, and the natural and social sciences, are characterized largely by the need to allocate limited resources. The contribution from OR stems primarily from: abstracting the essential elements and structuring the real-life situation into a mathematical model, exploring the structure of solutions and developing systematic procedures for obtaining them, and developing a solution that yields an optimal value of the system.

b) Decision Support Systems

Decision Support Systems are defined as interactive computer-based systems intended to help decision makers utilize data and models in order to identify and solve problems and make decisions. They facilitate the solution of unstructured problems by a set of decision-makers working together as a group.

This paper presents only the two aspects of decision support (making) disciplines—OR and DSS .

2.2. Operations Research and its Characteristics

The OR Society (as cited in Checkland, 1999:73) defines OR as follows:

> Operations research is the application of the methods of science to complex problems arising in the direction and management of large systems of men,

> machines, materials and money in industry, business, government, and defense. The distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as chance and risk, with which to predict and compare the outcomes of alternative decisions, strategies or controls. The purpose is to help management determine its policy and actions scientifically.

Likewise the OR Society of America (as cited in Pollock and Maltz, 1994:1) defined OR as:

- "...a scientific approach to decision-making."
- "...concerned with scientifically deciding how best to design and operate systems, usually under conditions requiring the allocation of scarce resources."

To allocate scarce resources equitably and in a reasonable manner they have to be managed efficiently. According to Murty (1995:1), for efficiency and optimization, we have to find the optimal level of combination and usage of the available resources. The branch of science, which deals with techniques for optimizing the performance of systems is OR . It is a scientific method that provides executives with a quantitative and rational basis of making decisions, especially those dealing with the allocation of resources. The focus of OR is on scientific methods of decision-making that seek to understand the complex operations of any system, to predict its behavior and improve its performance. Historically, as Heylighen indicates, it was a narrower area of activity that stressed quantitative methods and did not concern itself with tradeoffs between objectives and means or with problems of equity. However, OR, as understood today, is essentially identical to and is concerned with tradeoffs and multiple objectives.

On a wider basis, according to the British Operational Research Society (as cited in Graf, 2002), the purpose of OR is to help management determine its policies and actions scientifically. OR can be understood as the application of the scientific method to problems of high complexity. The term scientific, however, may be understood differently depending on the nature of the OR application. Scientific may mean a rigorous scientific method, or it may mean educated common sense.

The essential characteristics of OR, as identified by Thierauf & Klekamp (1975:9-13), are to:

a) Examine Functional Relationships from a Systems Overview

The activity of any function or part of an organization has some effect on the activity of every other function or part. In order to evaluate any decision or action in such an organization, it is necessary to identify all the important interactions and to determine their impact on the whole organization versus the function originally involved.

b) Utilize the Interdisciplinary or Mixed-Team Approach

A mixed-team of different disciplines can speak, for example, of physical problems, chemical problems, biological problems, psychological problems, social problems, and economic problems as these are characterized in nature. Actually, the various disciplines describe different ways of studying the same problem.

c) *Adopt the Planned Approach* (Updated Scientific Approach)

Operations research makes use of the scientific method, which has been updated to reflect technological advances, such as the computer. The updated version of scientific method includes mathematical modeling, use of the standard techniques of OR, establishing proper controls, and the utilization of computer capabilities.

d) Uncover New Problems for Study

All interrelated problems uncovered by the OR approach do not have to be solved at the same time, but, each must be solved with consideration for other problems.

2.3. The Art and Science of Operations Research

According to Taha (1997:5), as a decision-making tool, OR must be viewed as both a science and an art. It is a science by virtue of the embodying mathematical techniques it presents, and it is an art because the success of all the phases that precede and succeed the solution of the mathematical model depends largely on the creativity and experience of the OR team. (Pinkus & Dixson, 1981:3-4; 273) further indicate that by art we mean the skill necessary to achieve practical results using the scientific approach to problem-solving embodied in OR. Willemain (as cited in Taha, 1997:5) advises that effective OR practice requires more than analytical competence: It also requires, among other attributes, technical judgment (e.g. when and how to use a given technique) and skills in communication and organizational survival.

Thus, the scientific approach to problem solving is a process of seven phases as identified by Pinkus & Dixson (1981:4). The seven phases (see Figure II-2) —identification of a problem, definition of a problem, construction of a model, derivation of a solution, testing a solution, implementation of a solution, and evaluation of results are stated below as discussed by Pinkus and Dixson.

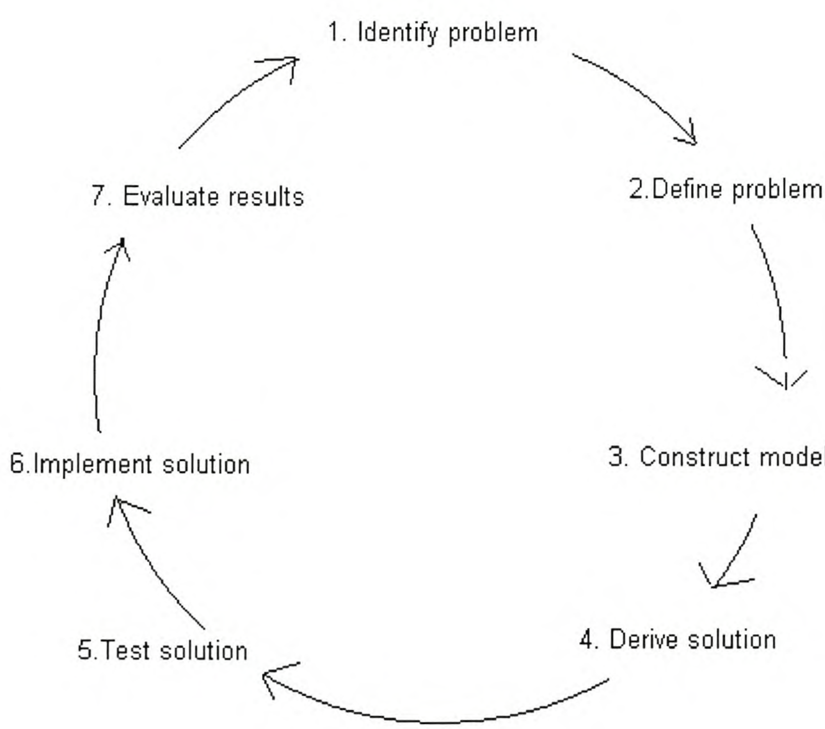


Figure II-2. Phases of a typical operations research study.

Source: Pinkus and Dixson (1981:4).

a) Identify Problem

Problems exist when there is a gap or disparity between the present situation and some desired state of affairs. These problems are identified in many ways. In the public sector, some of the most common are through a routine evaluation, often at year's end, which determines that goals are not being met; by complaints from the public about the delivery of a particular service; or by a need to economize, which usually means making more efficient use of the resources available to provide a particular service.

Ragsdale (2001:9) warns that if we do not identify the correct problem, all the work that follows will amount to nothing more than wasted effort, time, and money. Unfortunately, we are usually not faced with neat, well-defined problems. Instead, we often find ourselves facing a mess. Identifying the real problem involves gathering a lot of information and talking with many people to increase our understanding of the mess. We must then sift through all this information and try to identify the root problem or problems causing the mess. Thus, identifying the real problem (and not just the symptoms of the problem) requires insight, some imagination, time, and a good bit of detective work. Remember that the symptoms are just the tip of the iceberg.

Moreover, as Murty (1995:1-3) puts it, alongside problem identification, the decision variables have to be recognized. The important property of a decision variable is that its value has an effect on system performance, and there are mechanisms available by which we can change its value to any desired value within its specified operating range.

b) Define the Problem

The next step is to make a formal definition of the problem. Developing a formal problem definition requires an analysis of the situation and an understanding of the general background of the problem. It involves investigating the environment in which the problem exists, possibly gathering historical data, learning how a particular process works, and meeting with people who have firsthand knowledge of the problem.

Furthermore, problem definition involves defining the scope of the problem under investigation. This is a function that should be carried out by the entire OR team. The end result of the investigation is to identify three principal elements of the decision problem—namely (1) the description of the decision alternatives, (2) the determination of the objective of the study, and (3) the specification of the limitations under which the modeled system operates (Taha, 1997:5).

c) Construct a Model of the System

Once the problem has been defined, a model is built to represent the system within which it exists. This consists of mathematical (or economic or statistical) relationships based on the elements of the problem definition. It expresses the effectiveness of the system in terms of a set of variables, at least one of which is subject to control. When the controllable, or decision variables of the model are manipulated, they provide answers to the problem statement.

Model construction, as identified by Taha (1997:5), entails translating the problem definition into mathematical relationships. If the resulting model fits into one of the standard mathematical models, such as linear programming, a solution is usually attainable by using available algorithms. Alternatively, if the mathematical relationships are too complex to allow the determination of an analytic solution, the OR team may opt to simplify the model and use a heuristic approach, or the team may consider the use of simulation, if appropriate. In some cases, a combination of mathematical, simulation, and heuristic models may be appropriate for solving the decision problem. Turban & Aronson (2001:56) warn that since the model is the critical component in the decision-making process, it is possible to make a number of errors in its construction and use. It is critical to validate the model before it is used.

d) *Derive a Solution from the Model.*

Deriving a solution requires successive manipulations of the decision variables of the model in order to produce alternative values. This step is often carried out by computer, which allows many alternatives to be derived in a short time. The best solutions are those values of the decision variables that best satisfy the criterion or criteria established by the defined objective, subject to the constraints that have been placed on the problem. Murty (1995:1-3) indicates that an optimum solution is a feasible solution that has the most desirable value (s) for the objective function(s) among all feasible solutions.

e) Test the Solution

Having derived a solution, tests can be made to determine how sensitive this is to changes in the basic information. Would changes of particular magnitude, for example, invalidate the solution? If possible, a pilot scheme of the solution might be carried out and the results observed. Murty (1995:1-3) emphasizes the need of sensitivity analysis by stating that "To determine how robust the optimum solution is under inaccuracies in input data and structural assumptions, sensitivity analysis is essential, which validates the process." Taha (1997:6) clarifies that, model validity checks whether or not the proposed model does what it is supposed to do—that is, does the model provide a reasonable prediction of the behavior of the system under study? Does the solution make sense? Are the results intuitively acceptable?

f) Make a Decision and Implement

Eventually the study will be concluded and a set of recommendations will be made. At this stage public meetings are sometimes held to present and discuss the results of the study. Often input from the public will already have been received during the course of the study. Now the decision-makers must review and weigh the recommendations of the study in light of their experience and judgment, expert opinion, public pressures and political influences and a host of other intangible factors that surround the problem. Murty (1995:1-3) states that often the output from the model is not implemented as is. It provides insight to the decision maker who combines it with his/her practical knowledge and transforms it into an implementable solution.

Implementing the solution is often the most difficult. By their very nature, solutions to problems involve people and change. For better or for worse, most people resist change. Ragsdale (2001:10) advises that it is wise, if possible, to involve anyone who will be affected by the decision in all steps of the problem solving process. This not only helps the person develop a sense of ownership and understanding of the ultimate solution, but it can also be the source of important information throughout the problem solving process. Resistance to change and new systems can also be eased by creating flexible, user-friendly computer interfaces for the mathematical models that are often developed in the problem-solving process.

Implementation is an art that requires a systematic approach to facing reality. According to Taha (1997:6), implementation of a validated model involves the translation of the model's results into operating instructions issued in understandable form to the individual who will administer the recommended system. The burden of this task lies primarily with the OR team. According to Murty (1995:1-3), implementation requires checking for practical feasibility, making the necessary modifications in the model and solving it again if it is found to be impractical for some reasons; and repeating the whole process as needed.

g) Evaluate the Results

When implemented, the solution to a problem is expected to achieve some specific results—to accomplish some goal. A method of determining whether the result or goal has been accomplished should be developed and implemented at the time the solution is implemented in order to enable a future assessment of the solution in terms of the problem it is supposed to solve.

In practice, the process of identifying and solving problems is never-ending. Implementation of the solution to a problem creates a new situation and the potential for a new set of problems. Thus, most implemented solutions require monitoring and evaluation that may in turn lead to the identification of new problems requiring solution. Because of this circular aspect of problem-solving it is useful to follow the seven stages for an OR study as shown in Figure II-2.

Ragsdale (2001:11) notes that modeling techniques can only help make good decisions, but cannot guarantee that good outcomes will always occur as a result of those decisions. Even when a good decision is made, luck often plays a role in determining whether a good or bad outcome occurs. However, using a structured modeling approach to decision-making should produce good outcomes more frequently than making decisions in a more haphazard manner.

2.4. Soft OR—the Other Face of OR

Discussion about OR will not be complete without raising the issue of soft OR. Graf (2002) states that the need to serve society as a whole, by including those who have not been included in the decision-making process, operations researchers generated a new OR—what is now known as 'Soft OR', as opposed to 'Hard OR,' which concerned itself with the design of the mathematical/technical applications. According to this new view, OR can be scientific, it can be logical, and it can be common sense. Above all, it strives to assist those involved in problematic situations by giving them means to overcome and move forward. Graf (2002) continues by emphasizing the dominance of Soft OR:

> Life is a mess, we are in the swampland and we have to make some sense of what is going on. The only truth is based on subjectivity and different perceptions. The Operational Researcher is no more an expert than a facilitator who is trying to facilitate the client toward a reasonable (as opposed to optimum) resolution (as opposed to solution) of the situation (as opposed to the problem).
>
> Soft OR has gained prominence since the mid-60s and it is now arguably the case that the traditional approach of OR is but a subset of Soft OR. Soft OR involves modeling, but not in a mathematical sense, the differing perceptions and viewpoints of all those involved in a situation so that they may all understand each other better and thus come to some agreement. There are also methods, which are specifically geared to move the client(s) toward decision-making.
>
> The role of the Operational Researcher is to facilitate the process and engage the client in the content of the problem. OR in this sense is not as easy as playing with mathematical models in the backroom! The nature of concept definition and comparison is highly qualitative, as opposed to quantitative. There are pictures and diagrams and comparative scales made up of nothing more than statements like 'preferred' or 'unreasonable'.

In line with the above argument, as an applied discipline OR is concerned with real-life problems and with people who need to deal with these problems. It is one of any approaches to real-life problem solving characterized by an analytical (i.e. model-and-data-based) way of looking at things. According to Fortuin, Van Beek, and Van Wassenhove (1996:1), it is this analytical side of OR that can create problems. Too much emphasis on mathematical tools and techniques may severely hamper the usefulness of OR to human decision makers working with real people in real organizations. Good practice in OR means appropriate analytical skills as well as adequate softer skills— including teamwork and facilitation.

2.5. OR and Other Related Fields

2.5.1 Systems Approach and Operations Research

According to Cook and Russell (1989:23), OR is the application of scientific or systematic methods to improve the decision-making process. The OR approach assumes a systems viewpoint from which scientific procedures can be applied to various aspects of an entire problem. A systems approach helps us to have a balanced perspective concerning an organization's components, and to view the organization as a component, or subsystem, of the environment in which it exists. The advantage of the systems approach is that it allows the optimization of an organization's overall goals, not just those of isolated departments.

Taking further the views of Cook and Russell, the Office of National Drug Control Policy (1999) cites problems of substance abuse and criminal activity. It indicates that multidisciplinary systems approach to dealing with these problems regards them as interrelated problems instead of separate and isolated behaviors. Cross-agency programs increase program effectiveness, generate significant financial savings, and increase public safety. Systems approach is needed in dealing with these problems and the implementation of cross-agency efforts. Each organization brings different ideas and priorities to the table, and the end result is more effective than if each organization tried dealing with the problems on its own.

According to Checkland (1999:60), as the complexity of the subject matter increases there are limitations of the scientific methods. It is because of the problems of complexity that systems thinking develops. The world is a giant complex with dense connections between its parts. We cannot cope with it in that form and are forced to reduce it to some separate areas, which we can examine separately. Our knowledge of the world is thus necessarily divided into different 'subjects' or 'disciplines', and in the course of history these change as our knowledge changes. It is not nature which divides itself up into physics, biology, psychology, sociology, and the like; it is we who impose these divisions on nature. However, after analysis we need to integrate the knowledge accumulated by the different disciplines and perspectives in order to hold a holistic view of the problem and situation.

Operations research is often described as a kind of systems analysis because of its preoccupation with the connections rather than with the parts. According to Ecker and Kupferschmid (1988:3), OR differs somewhat in philosophical outlook from most physical sciences because of the nature of the system that it studies. The analytical approach to problem solving is typically reductionist in that it approaches complicated problems by decomposing them into simpler parts each of which can be understood more easily in isolation. Unfortunately, the behavior of organizations and other complex systems is often determined more by the interconnections between parts than it is by the inner mechanisms of the parts themselves, and in many cases the phenomena of interest in OR study would be rendered invisible by conceptually dissecting the system. The challenge to the OR analyst is thus to construct models that give a simplified description of mechanisms, but which are also holistic in that they do not assume away important aspects of system structure.

Ciliers (1998:141) is critical of the analytical method (carving things up), deductive logic, atomism, formal rule-based grammars, closed algorithms and symbolic representation. The shortcomings of these approaches have been pointed out in analysis of information theory, and in formal symbol systems. As an alternative, he proposed a connectionist approach, arguing that this approach is intrinsically more sensitive to complexity. It focuses on the behavior of collections of many interconnected, similar elements that do not have (atomistic) significance by themselves, but that obtain significance through a complex set of no-linear, asymmetrical relationships in a network.

In line with this argument, the Health Systems Group indicates that systems thinking complements our natural tendency to break things down into manageable parts, also known as analysis or reductionistic thinking. Systems thinking explores expansionistic thinking, an approach that considers the context of a problem before breaking it down into its component parts. Moreover, Heylighen (1998) points out that the systems approach integrates the analytic and the synthetic methods, encompassing both holism and reductionism.

2.5.2. Policy Analysis and Operations Research

Policy analysis includes and extends the full range of ideas and analytical techniques, *inter alia,* from OR and systems analysis, cost-benefit analysis, economics, simulation, and decision analysis and explicitly considers the political and social impacts. The latter aspects are best taken into account by relying heavily on the intuition, judgment and experience of the public sector officials.

According to Gass (1994:28-29), policy analysis problems are of two kinds:

a) Well defined in that a problem has a clear-cut description and its solution is amenable to rigorous analysis as the problem basically deals with technological or physical questions; and
b) Ill-defined (squishy, messy, and wicked) in that the problem description has a high behavioral content for which there is a lack of theory, and it is overlaid with strong political implications.

Policy analysis is difficult as public sector problems usually do not have a definitive, singular formulation. They are multiobjective, and solutions are either good or bad, not optimal. The final decision is often based on political judgment, hopefully aided by an objective and comprehensive OR -based analysis.

Moreover, although there is successful application of OR in the technical problems and well-defined organizational issues, Banks & Rossini (1995: 61-62) observe that there is a relative lack of success when applied to complex social situations. The generic reasons for the failure of quantitative methods as applied to policy-related problems are:

a) Problems at the political technical interface, involving the general relationship between scientific and technical knowledge and the political process in modern society;
b) Problems related to the level of sophistication of the quantitative techniques applied to a situation;
c) Issues of timing between the analytical process and the real world dynamics of a policy problem;
d) Problems related to obtaining adequate and accurate data; and
e) Various methodological issues, such as:

- Issues of timing between the analytical process and the real world dynamics; and
- Problems related to obtaining adequate and accurate data.

2.6. Multidisciplinarity of Operations Research

Brewer (1999:328) highlights the multidisciplinarity of OR by presenting some questions that OR seeks to answer. Interdisciplinary and problem-oriented inquiry, when effectively and successfully executed, consistently consider a variety of intellectual and practical questions not normally asked in ordinary disciplinary pursuits:

a) What goal values are sought and by whom?
b) What trends affect the realization of these values? Or, where did the problem originate?
c) What factors are responsible for the trends? Or, what are the driving or influencing conditions?
d) What is the probable course of future events and developments—especially if interventions are not made? and
e) What can be done to change that course to realize or achieve more of the desired goals, and for whom?

No single decision maker is sufficiently multilateral to tackle this multitude of issues and to understand the ramifications of proposed solutions on all aspects of the organization, including its internal and external environments. Cook and Russell (1989:10) indicate that often a team of specialists is formed to attack quantitative management problems. The concept of team approach to decision-making is a key characteristic of the OR approach. To Brewer (1999:328), interdisciplinarity generally refers to an appropriate combination of knowledge from many different specialties- especially as a means to shed new light on an actual problem. In notably effective efforts, the combination of disciplines adds value: the total is more interesting than the sum of the individual contributions or parts.

According to Corbett and Van Wassenhove (1996:298), during its World War II origins, OR was conceived as a new way of solving problems characterized by the interdisciplinary nature of the groups performing OR work. Being at the heart of OR, the question of interdisciplinarity has received much attention in the debate. A mathematical approach, or simply an analytical style or logical thought, is an important characteristic of OR, but it is precisely the dominance of mathematics over other disciplines that has attracted much criticism.

In particular the behavioral sciences are deemed to have been neglected by the OR community. Beged-Dov (as cited in Corbett & Van Wassenhove, 1996:298) expressed his concern by stating "The single greatest obstacle to the establishment of operations research as powerful discipline noted for actual accomplishments is the fact that an ever increasing number of narrow specialists in mathematics and natural sciences impart to our profession undesirable dogmas and outlooks." Morse (as cited in Corbett and Van Wassenhove, 1996:299) also observed narrowing in outlook of many OR workers.

In line with the above criticism, Taha (1997:3) indicates that the mathematical aspect of OR should be viewed in the wider context of the decision-making process. The criticism of the dominance of one discipline, i.e. mathematics, is substantiated by many authors. Karlqvist (1999:379) states that as science moves closer to applications, decision-and policy making, problems occur that cannot be confined to narrow disciplines. We must go beyond disciplines and venture into territory commonly known as interdisciplinary research. French *et al.* (1986:1), also emphasize the multidisciplinarity of OR by indicating that none of OR problems can be solved by methods that lie entirely within the area of a single discipline. Thus a successful OR worker must be 'A jack of all trades and, to counter the proverb, the master of most as well'.

In line with the above mentioned necessity Brewer & Lövgren (1999:315) observed that interdisciplinary work has attained much prominence in recent years, especially as many realistic problems have proven unyielding to ordinary discipline-based approaches. This situation occurs routinely in efforts to define, analyze, and come to terms with the many complex challenges presented by environmental problems. According to Corbett and Van Wassenhove (1996:299), particularly when the decisions involved acquire a more strategic nature, incorporating the perspectives offered by several different disciplines is a *sine qua non.* Given that much successful OR work is performed in interdisciplinary teams, issues such as team management and communication between the various team members become highly relevant.

Furthermore, Taha (1997:3) stresses the importance of interdisciplinarity in a problem solving process. He clearly states that though mathematical models are the cornerstone of most OR studies, there is more to the solution of the decision-making problem than the construction and solution of the mathematical model. Specifically, decision problems usually include important intangible factors that may not be readily quantifiable. Foremost among these factors is the presence of the human element in most decision environments. Indeed, decision situations have been reported where the effect of human behavior has so influenced the decision problem that the solution obtained from the mathematical model is deemed impractical. Taha (1997:3) further illustrates these cases by the widely circulated elevator problem:

> In response to tenants' complaints about the slow elevator service in large office building, the situation was analyzed using a waiting-line model. However, the proposed solution to speed up the elevator service did not alleviate the problem. Further study of the situation revealed that the tenants' complaints were more a case of boredom, and the problem was solved by installing full-length mirrors at the elevator entrance. The complaints disappeared as the elevator users were kept occupied watching themselves and others while waiting for the elevator service.

This simple example demonstrates that solutions to social problems are not satisfactorily solved by a single discipline. On similar issues, Keyfitz (1995:21) argues that the range of disciplines converging on a single question is increasing. The social usefulness of the social sciences has always revolved around their application to policy, while the physical sciences stayed with physical problems. But now policy advice is not offered by social science alone; there are strong incentives to physical science to enter that field. Writings on atmospheric warming and what ought to be done about it are signed by authors from a dozen disciplines, each showing the marks of his or her own disciplinary background.

Some benefits of the multidisciplinary approach are identified by Policansky (1999:388) as well. First, its reports are credible. Second, true interdisciplinary efforts are usually the result of long-standing group activities, often focused on one or a few difficult core problems. Time and circumstances allow people from several different disciplines to work together on problems in such a way that their solutions reflect a melding of knowledge and transcend the limitations of any single discipline. According to Hansson (1999:339), interdisciplinarity is a means of transforming science from the realm of the general and abstract to the full complexity and specificity of concrete reality.

Despite its wide applicability and usefulness, there are some obstacles confronted by those who do interdisciplinary work. They are identified by Brewer (1999:335) as:

a) Different cultures and frames of references;
b) Different methods and operational objectives within and between the disciplines;
c) Different 'languages' within the disciplines and between the disciplines and the world at large;
d) Personal challenges related to gaining the trust and respect of others working in different disciplines and fields;
e) Institutional impediments related to incentives, funding and priorities given disciplinary versus interdisciplinary work; and
f) Professional impediments related to hiring, promotion, status, and recognition.

It has been discussed that OR has been multidisciplinary in nature from its origin. Hence, it must not be discouraged because of the above mentioned obstacles. It has to find its way to successful operation by considering the obstacles as an advantage to help it gain diversity, to sharpen its edge and to widen its solution horizon.

2.7. Modeling for Decision and Insight

2.7.1. Models and Operations Research

Operations research is a discipline that makes much use of modeling techniques. In fact, according to Cook and Russell (1989:23), the characteristic most distinguishing the OR approach is its use of models. Mathematical models attempt to translate the essential qualities of real-world situations into systems of equations. Nevertheless, manipulating or solving the mathematical models can engender effective strategies or courses of action for the decision maker. Dickson (as cited in Chicken & Hayns, 1989:1) warns that "The product of an arithmetical computation is the answer to an equation: it is not the solution to a problem." There is no safety in numbers.

Ecker and Kupferschmid (1988:2) define a model as an appropriate abstract representation of a real system. A model will map most of the relevant features, and neglect less important aspects to:

a) Provide insight into the problem;
b) Permit experimentation but avoid expensive and/or dangerous experiments

c) Avoid the production of unwanted side products;
d) Optimize some objectives; and
e) Propose careful use of resources.

Because of the above-mentioned advantages, models are used in many policy arenas to predict the future consequences of current decisions. Korfmacher (1998:35) views a model as a typically objective means of processing complex information to predict future conditions. Furthermore, as Roy (1996:15) puts it, a model is considered objective only if, in the eyes of a certain audience, it constitutes:

a) An impartial and unbiased representation of the class of phenomena that it is to reflect within the context of the questions considered; and
b) An impartial and unbiased vehicle for investigation or communication, given the class of phenomena represented and the manner in which they have been taken out of their context.

However, as identified by Ecker and Kupferschmid (1988:2), with respect to socio-economic modeling, scientists have found that models frequently do not live up to these promises—they often incorporate the modeler's biases, are difficult for decision makers to use, and do a poor job of predictions. In this case, there may be a danger of poor policy outcomes. According to Zijm (1996:129), to be of use for better policy outcomes good model building requires that all essential elements of a physical situation or an organizational problem are captured. On the other hand, such a model should remain tractable, requiring a rather deep knowledge of existing solution techniques. Once having established model and data analysis, the development of algorithmic or heuristic solution methods is less time consuming. Their implementation, in particular, programming and the development of software tools based on these methods, absorb a major amount of time, although they require less intellectual activities.

According to Cook and Russell (1989:10), by using models, we can investigate certain cause-and-effect relationships and the interaction between key variables, including decision makers. Boulden and Buffa (as cited in Corbett and Van Wassenhove, 1996:302) conclude that decision-making is facilitated because the manager interacts with the model, not because decision-making logic is built into the model itself.

Ecker and Kupferschmid (1988:8) further identify the following points as useful to remember when trying to build a model:

a) There will be no precise recipe telling the user how to build a model;
b) Experience and judgment are two important aspects of model building;
c) There is not necessarily a correct model; and
d) There is no concept of a unique model, as different models focusing on different aspects may be appropriate.

To complement the process of model building, Ragsdale (2001:9) warns that the goal at the model-formulation stage is to select a modeling technique that fits the problem, rather than trying to fit the problem into the required format of a preselected modeling technique. According to Monahan (2000:7), model building is more art than science. When addressing a complex problem, there are typically no signposts that indicate which are the important relationships that must be maintained and which are the ones that can either be ignored or highly simplified. Choosing what to include and how to include it and what to leave out requires experience, ingenuity, and other intangible factors that cannot be easily taught. For this reason, in the modeling process human beings will always play an increasing role. This is recognized by Kallrath and Wilson (1997:393) and they state that even with growing hardware and software capabilities analysts will become more important. When hardware and software capabilities grow there is demand for more complex and realistic models because clients will ask for more details in the model.

Although the insight and understanding gained by modeling problems can be helpful, decision-making often remains a difficult task. The two primary causes for this difficulty are uncertainty regarding the future and conflicting values or objectives (Ragsdale, 2001: 4-5). As with other models the accuracy of a computer model is a function of human judgment, which creates the rules for selecting and manipulating elements (O'Sullivan, & Rassel, 1989: 10). To solve the dilemma of conflicting objectives, Cloete (2002a) proposes that complex policy decisions with multiple policy objectives that may be contradictory, need to be prioritized in terms of different decision criteria. The increasing use of decision technologies in governance makes it possible to achieve these objectives. However, Cloete warns that the adoption and use of more user-friendly but effective electronic DSS will not necessarily guarantee policy and service delivery success. They only can maximize the potential *for* improved *or* more successful results if they are applied correctly.

2.7.2. Optimization Models

2.7.2.1. Linear Programming

Linear programming (LP) is an extremely important branch of optimization that finds many applications in industry, business, and government (Murty, 1995: 22). Linear programming models are most effective at the operational level of decision-making. Decisions at this level, with a single objective and relative ease of problem definition, are well suited to linear programming analysis. However, at the policy level there are too many uncertainties for a linear programming analysis to be effective. Hence, at higher levels of decision-making multiple objective programming is more suitable.

According to Ragsdale (2001:63), LP is particularly well suited to problems where scarce or limited resources must be allocated or used in an optimal manner. One of the most fundamental of the decisions a public administrator must make is the determination of how scarce resources should be allocated to competing activities. These scarce resources may be budgeted dollars, land for housing, human resources, equipment, or any other factor over which the administrator exercises control.

Despite its wide applicability, linear programming techniques have some limitations when applied to the public sector environment. Byrd (1975:109-110) identifies the following:

a) The first technical limitation involves the assumption that the objective function and constraints behave linearly. However, many social and economic problems are nonlinear and have to be dealt with by nonlinear programming.
b) The second technical limitation is that a linear programming model gives a fraction of a number as a solution when the solution is supposed to be an integer. Integer linear programming can handle such problems.

Adding to the limitation to the LP solutions, Taha (1997:111) indicates that the optimal solution of a linear programming problem represents a snapshot of the conditions that prevail at the time the model is formulated. However, in the real world, decision environments rarely remain static, and it is essential to equip linear programming with the capability to determine changes in the optimal solution that result from making changes in the parameters of the model. This is what sensitivity analysis does. It provides efficient computational techniques that allow us to study the dynamic behavior of the optimal solution.

2.7.2.2. Nonlinear Programming

Ecker and Kupferschmid (1988:259) state that problems in which the objective and constraint functions are not linear are called nonlinear programs. They further indicate that nonlinear problems arise unavoidably in engineering applications such as process design and optimal control. In addition, many problems are really nonlinear, and the simplifying approximation of linearity may be justified for only some values of problem data. Thus, many of linear programming applications give rise to nonlinear programming formulations when economies of scale and other effects cause departures from strict proportionality between inputs and outputs.

Ragsdale (2001:336; 337) states that some types of optimization problems involve objective functions and constraints that cannot be modeled adequately using linear functions of the decision variables. These types of problems are called nonlinear programming problems. Nonlinear problems can have a nonlinear objective function and/or one more nonlinear constraints.

Nonlinear programming has wide spread applications in real life. Pinkus and Dixson (1981:92; 186) indicate that, among other things, nonlinear programming can be used to determine the shortest distance traveled between supply and service locations and to minimize the total time needed to deliver services. It also can help to evaluate a number of different arrangements (groupings) of service centers in order to be able to minimize cost. For example, it has been used by local governments in England to determine the best number of plants, their location and the areas they should serve. The output of this nonlinear programming model was used to decide on the best long-term refuse disposal policies.

2.7.2.3. Dynamic Programming

According to Byrd (1975:139), dynamic programming models are one class of models that are quite versatile in application. They are particularly useful whenever a sequence of decisions must be made and the goal is to find the combination of decisions that optimizes the overall effectiveness of the entire set of decisions. Moreover, Turban & Aronson (2001:171) point out that dynamic models are important because they use, represent, or generate trends and patterns over time. They also show averages per period, moving averages, and comparative analysis.

With its flexible structure, dynamic programming can be of considerable use in public administration. Byrd (1975:151) indicates that applications of dynamic programming that could be of benefit in public administration involve the development of employment hiring and leveling strategies for large scale public projects, the development of strategies for funding a series of public projects, and the development of strategies for the scheduling of public projects. However, the optimization of decision-making with multiple and conflicting objectives is difficult to incorporate into a dynamic programming model.

In addition, dynamic programming is a future oriented modeling technique. Thierauf (1982:107) shows that dynamic programming takes into account the effect of current decisions on future periods and adjusts every decision to yield the best overall performance. Models of this type are especially suitable for processes that extend over a number of time periods. Examples are truck-routing problems, and the replacement of machines or facilities.

2.7.2.4. Goal and Multiobjective Programming

As goal and multiple objective programming have wide applications in the public sector decision-making processes, they will receive more attention and their application in the Eritrean public sector will be demonstrated using Excel add-in program (Premium Solver Platform) in Chapter IV.

According to Goodwin and Wright (1991:7), many decision problems involve a number of objectives, and often these objectives conflict. For example, a local authority, faced with a decision on the route of a new road, might have to balance objectives such as minimizing cost and minimizing environmental damage. If the route incurring the lowest construction costs would also lead to the destruction of an important wildlife habitat then some judgment would have to be made about the relative importance of the objectives.

In addition, Ragsdale (2001:297) indicates that in business and government different groups of people frequently pursue different objectives. Therefore, it is quite possible that a variety of objective functions can be proposed for the same optimization problem. According to Cook & Russell (1989:354), these problems cannot be handled by linear and integer programming, which address problems that have a single objective such as cost minimization, profit maximization, or some other unidimensional objective. However, many decision problems involve multiple objectives, some of which are incompatible or conflicting. For example, a company might want to maximize profits, minimize costs, improve its quality of service, and increase its warehouse inventories. Some of these objectives are incompatible in that one can be accomplished only at the expense of another. These kinds of conflicts are common in the realm of real-world decision-making. In fact, decision-making has been loosely defined as a struggle to resolve the dilemma of conflicting objectives.

Likewise, Rardin (1998:59-60) observes that even though in many business and industrial applications, single objectives realistically model (like linear programming) the true decision process, this is not the case in the public sector. Business organizations often are really satisfied to maximize some measure of profit or minimize some cost. Matters become much more confused when the problem arises in the government sector, or in complex engineering. In such applications, solutions may be evaluated quite differently by different participants in the decision process, or against different performance criteria. According to Murty (1995:280), to capture all the perspectives, a goal programming approach is perhaps the most popular optimization technique for the multiobjective problems. This maximizes or minimizes more than one objective function at the same time. Another aspect that necessitates the use of multiobjcetive programming is pointed out by Rardin (1998:376) who says that many, perhaps most, government planning problems are multiobjective because they involve competing interests and objectives that are difficult to quantify in monetary terms. In such situations the goal programming approach is perhaps the most popular for handling multiobjective problems (Murty, 1995: 280).

Such multiobjective optimization problems, as pointed out by Ragsdale (2001:297), require an iterative solution procedure in which the decision maker investigates a variety of solutions to find which is most satisfactory. In these problems, we might need to solve several variations of the problem before we find an acceptable solution. According to Taha (1997:349), there are situations where the system may have multiple (possibly conflicting) objectives. For example, aspiring politicians may promise to reduce the national debt and, simultaneously, offer income tax relief. In such situations, it may be impossible to find a single solution that optimizes the conflicting objectives, instead we may seek a compromise solution based on the relative importance of each objective. In this situation, as identified by Cook and Russell (1989:6), goal programming and multiobjective linear programming were developed to deal with decision problems that have multiple and sometimes conflicting goals.

In multiple goals, those with higher importance need to be given more weight. Weights express the relative importance of each input to a processing element and ultimately the outputs (Turban & Aronson, 2001:611). Ragsdale (2001:302; 322) further indicates that weights are assigned to the deviational variables in the objective function of a goal programming problem to better reflect the importance and desirability of deviations from the various goals. For each goal, we need to create a deviation function that measures the amount by which any given solution fails to meet the goal (either an absolute or a percentage). Unfortunately, no standard procedure is available for assigning values to the weights in a way that guarantees the most desirable solution to a goal programming problem. Rather, one needs to follow an iterative procedure in which one tries a set of weights, solve the problems, analyze the solution and then refine the weights and solve the problem again. One needs to repeat this process many times to find a solution that is the most desirable to the decision maker.

2.7.3. Simulation

Simulation analysis is a widely used OR tool in public administration. Simulation models are an effective method for the analysis of situations in which exact solutions by precise mathematical methods are difficult to obtain. According to Taha (1997:4), an alternative approach to modeling a complex system is simulation. Simulation modeling is the next best thing to observing a real system. It differs from mathematical modeling in that the relationship between the input and output need not be stated explicitly. Instead, it breaks down the real system into (small) modules and then imitates the actual behavior of the system by using logical relationships to link the modules together.

Turban & Aronson (2001:189) indicate that simulation is usually used only when a problem is too complex to be treated by numerical optimization techniques. That is when the problem either cannot be formulated for optimization (e.g. because the assumptions do not hold), the formulation is too large, there are too many interactions among the variables, or the problem is stochastic in nature (exhibits risk or uncertainty).

Cook and Russell (1989:588) cite the following as successful applications of simulation in the public sector:

a) *Health care applications*: to predict the effect of various physician mixes on the utilization of resources, and to plan the configuration of emergency rooms, and other hospital facilities;
b) *Urban applications*: problems such as police dispatching, the planning and design of transit systems, evaluating operating alternatives at airports, garbage collection, the location of emergency vehicles, and long range financial planning can be solved using computer simulation;
c) *Financial applications*: all kinds of pro forma statements are produced using financial simulation packages;
d) *Military applications*: large-scale military battles as well as individual weapons systems have been simulated to aid in the design both of weapon systems and of strategic and tactical operations; and
e) *Agricultural applications*: to predict the effects of various policy alternatives and to aid in the design of regional grain collection, handling, and distribution.

As with most other techniques, simulation has its advantages and disadvantages. The major advantage of simulation, as identified by Winston (1993:1183), is that it is relatively straightforward. In general, simulation methods are easier to apply than analytical methods, whereas analytical models may require us to make many simplifying assumptions, simulation models have few such restrictions, thereby allowing much greater flexibility in representing the real system. Once a model is built, it can be used repeatedly to analyze different policies, parameters, or designs.

2.7.4. Forecasting

The importance of forecasting is highlighted as almost all managerial decisions are based on forecasted information. Policy decisions of governments and nonprofit organizations are dependent on quality forecasts.

Caulkins (2002:486) shows that policy analyses are almost always about contemplated future outcomes, and the future is always uncertain. There are exceptions, such as retrospective analyses prompted by legal disputes and evaluations of current interventions. According to Taha (1997:505), in decision-making, we deal with devising future plans. The data describing the decision situation must thus be representative of what occurs in the future. For example, in inventory control, we base our decisions on the nature of demand for the controlled item during a specified planning horizon. In addition, in financial planning, we need to predict the pattern of cash flow over time.

Aoron (2000:193) sees that all public policies have two things in common. They deal with the future and, as a result, they are based on forecasts or projections. The forecasts or projections may be implicit or based on naïve extrapolation or ad hoc assumptions. They may also be explicit and based on elaborate extrapolations or on behavioral models. In either case, unfortunately, they are notoriously unreliable. Nonetheless forecasts are what distinguish reasoned planning from blind action. Without forecasting, we would be totally at sea. Furthermore, Lynn (1994:23) emphasizes the importance of forecasting by stating that if the lights that guide us ever go out, they will fade little by little, as if of their own accord. Confining ourselves to practice, we may lose sight of basic principles, and when these have been entirely forgotten, we may apply the methods derived from them badly, or we might be left without the capacity to invent new methods, and only be able to make clumsy and unintelligent use of wise procedures no longer understood.

According to Cook & Russell (1989:498-499), all quantitative forecasting techniques depend upon the existence of adequate and accurate historical data. However, even if adequate data do not exist but the forecast is important, there are qualitative techniques that can be employed to yield better results than a 'gut-feeling' or 'seat-of-the-pants' forecast.

2.7.5. Service (Queuing) Models

Waiting for service is part of our daily life, and the waiting phenomenon is not an experience limited to human beings only: jobs wait to be processed on a machine, planes circle in stack before given permission to land at an airport, and cars stop at traffic lights. Unfortunately, we cannot eliminate waiting without incurring inordinate expenses. We cannot get rid of queues; in fact, all we can hope to achieve is to reduce the adverse impact of waiting to acceptable levels (Taha, 1997:607). According to Cook and Russell (1989:545), queuing models are usually applied to minimize two kinds of costs: those associated with providing service and those associated with waiting time. The costs can be financial or intangible (like customer dissatisfaction).

If the configuration of the queuing system is not appropriate, service delivery will be hampered. Byrd (1975:11) warns that in public systems the consequence of waiting lines can be quite severe when the queuing system is a court and the waiting item is a person residing in jail awaiting his trial. The provision of an efficient court system is just one example of the use of queuing theory in public systems analysis. Likewise, the consequence of waiting may be more severe in cases like hospital emergency rooms.

According to Ragsdale (2001:629), in many queuing problems, management has some control over the level of service provided. For example, customer waiting times could be kept to a minimum by employing a large number of servers. However, this can be expensive, or actually wasteful, if an excessive number of idle servers is maintained. On the other hand, employing a small number of servers keeps the cost of providing service low, but is likely to result in longer customer waiting times and greater customer dissatisfaction. Thus, a trade–off exists between the cost of providing service and the cost of having dissatisfied customers if service is lacking. The nature of trade-off is shown in Figure II-3.

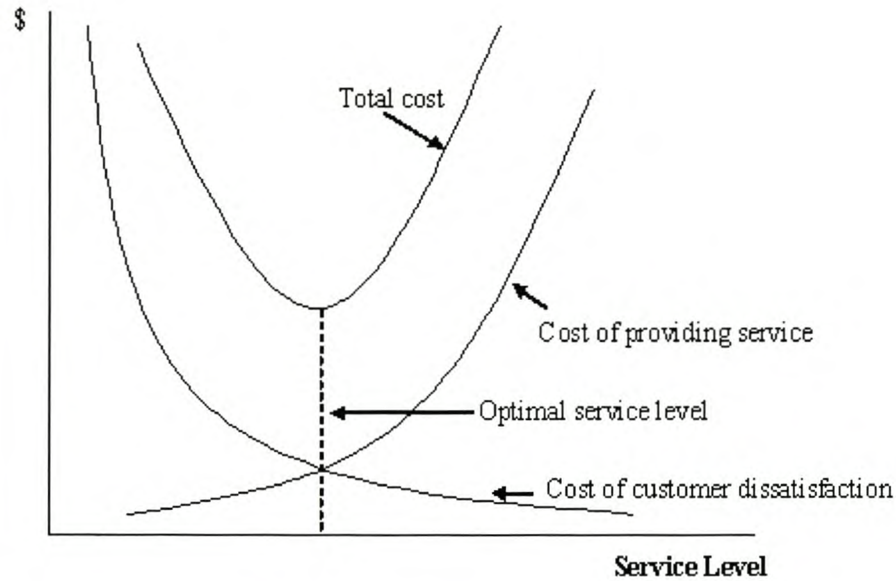


Figure II-3. Trade-off between costs of providing service and customer satisfaction.

Adapted: Taha (1997:608).

Figure II-3 shows that as service levels increase, the cost of providing service also increases, but the cost of customer dissatisfaction decreases (as does the length of time customers must wait for service). As service levels decrease, the cost of providing service also decreases, but the cost of customer dissatisfaction increases. The objective in many queuing problems is to find the optimal service level that achieves an acceptable balance between the cost of providing service and customer satisfaction.

2.7.6. Inventory

A business or an industry usually maintains a reasonable inventory of goods to ensure smooth operation. Taha (1997:439) indicates that traditionally, inventory is viewed as a necessary evil—too little of it causes costly interruptions, too much results in idle capital. The inventory problem determines the optimal inventory level that balances the two extreme cases. By optimal level we refer to minimum cost lot sizes where costs consist of setup or ordering costs, inventory holding costs, and shortage costs (Lotfi and Pegels, 1996:301).

Public institutions, like their industrial counterparts, maintain supply and service operations to meet their agency's mission. The goal of supply systems is to balance the costs of supplies and the consequences of being out of stock. The lack of supplies (inventory) in emergency situations may result in substantial public inconvenience. On the other hand if the item that is out-of-stock is essential, extra cost will be incurred to procure it in an inefficient manner.

To counter the above problems inventory and purchasing managers are charged with making the following basic decisions which will affect inventory service level and the cost of inventory: *when* to order, *where* to order, *how much* to order, and *what* the proper logistics are (Cook and Russell, 1989:633-634). To make these decisions and manage the inventory effectively, medium to large organizations need sophisticated computer-based DSS. The basic functions of a decision support system for inventory management are inventory accounting, demand forecasting, inventory decision-making, and inventory reporting.

The useful applications of inventory models in the public sector are observed by Byrd (1975:10). He indicates that:

> In traditional sense, inventory models could be very useful in keeping down the inventory costs in many government agencies, including schools, hospitals, and highway departments. In a conceptual sense, inventory models could be developed to determine the best number of government facilities for a given population. For example, how many fire stations should be provided in an urban area? In this case, the cost of inventory would be the cost of maintaining the fire station, while the cost of not having the inventory when demanded would be the costs of property damage and the lives lost.

2.8. Project Scheduling

One area of OR that has found its way into public systems is project management. Project scheduling is one of the few applications of management science that is widely used among both large and small organizations. Project managers must know how long a specific project will take to finish, what the critical tasks are, and what the probability of completing the project within a given time span is. In addition, it is often important to know the effect on the total project of delays at individual stages. For these and other reasons, several techniques have been created upon which project managers rely.

To solve such problems two techniques—Critical Path Method (CPM), and Program Evaluation and Review Techniques (PERT)—were developed during the 1950s concurrently but independently. According to Ragsdale (2001:661), one of the key ideas of PERT/CPM is that any project can be broken down into component activities that require different amounts of time and that must be accomplished in a specific order.

To be amenable to the techniques, the project activities must be listed in order. According to Lotfi & Pegels (1996:385), projects typically are divided into a group of tasks or activities that can be performed back to back (in series) or simultaneously (in parallel). The purpose of doing this is to identify the set of activities critical to a timely completion of the entire project. Large numbers of sequential activities tend to create 'bottlenecks' or critical paths. It is the objective of the PERT/CPM technique to identify the critical path. Management then can apply its efforts to alleviate any delays in the activities that are on the critical path and these ensure that a project will be completed as scheduled. According to Byrd (1975:51), the use of PERT/CPM techniques can be a very effective means of planning and controlling public projects. Perhaps the greatest benefit is that it forces *prior planning* to occur. By doing this, the project manager can identify many rather obvious bottlenecks ahead of time and can deal with them adequately rather than having these problems occur while the project is in progress, when the time delays are more serious.

Likewise, Cook and Russell (1989:292) stress the need for ordering, timing, and *assigning of responsibilities to individuals*. They say that when confronted with the task of scheduling and controlling a project of significant size and scope, you must identify each of the tasks involved. In addition, time estimates for each task must be developed, and the necessary resources, both human and nonhuman, must be identified. To accomplish this primary task, it is often desirable to use a work breakdown structure. The smallest element in the work break down structure, the work package, is defined in detail. Each work package identifies the resources and time it requires, all important precedence relationships, and the individual who is responsible for that work package. When all work packages are completed the project is complete. Moreover, according to Ragsdale (2001:661), successfully completing a project of any size requires a thorough analysis of the tasks involved, accurate estimates of the time and resources required, and a good understanding of the physical and logical interdependencies. Keeping track of all these details for even a relatively small project can be overwhelming.

By keeping track with all of the required steps, a project is likely to be completed on time. However, in some situations there may be a need to complete a project ahead of schedule. In this circumstance, we can use linear programming to help determine the least costly way of crashing a project to meet certain deadlines. Various linear programming techniques can be used to analyze CPM networks and to determine optimal crash schedules for projects. Moreover, according to Ragsdale (2001:689), crashing a project can be seen as a multi objective linear programming model. Two objectives can be pursued in this crashing model. On the one hand, we might want to minimize the finish time of the project. On the other hand, we might want to minimize the cost of crashing the project. These two objectives are in conflict with one another because reducing the completion time of the project increases the crash costs.

Another way to study the cost/time trade-off is to resolve the problem several times to determine crash cost for each possible completion time. A graph showing the minimum crash cost or each possible completion time is useful in evaluating the trade-offs involved in crashing. This relationship is shown in Figure II-4.

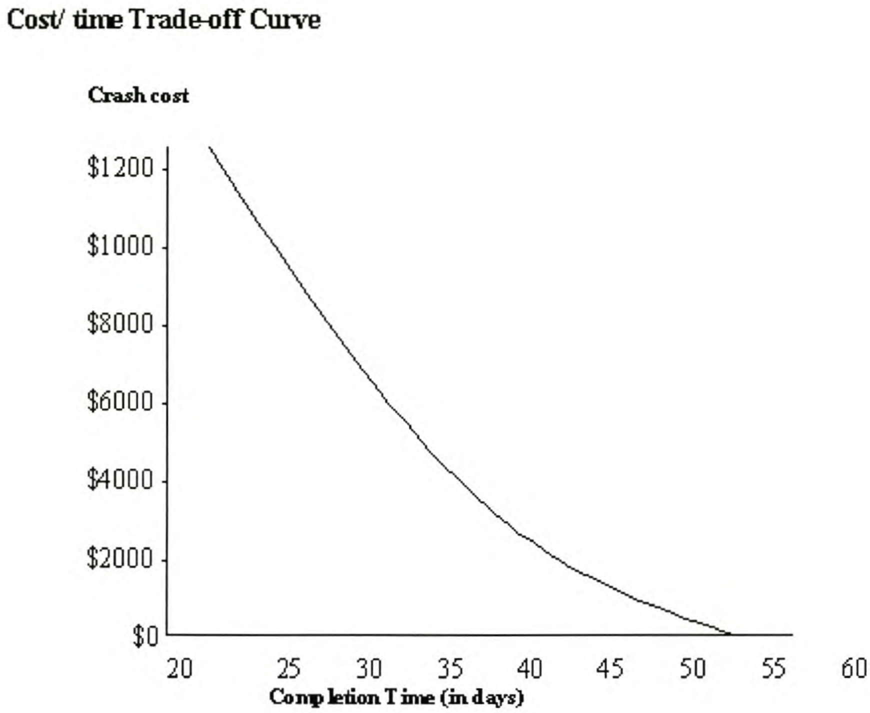


Figure II-4. Graph of the relationship between crash time and completion time.
Source: Ragsdale (2001:691).

With or without computer aid, PERT/ CPM is a powerful management tool that can be used as effectively in public projects as it has been in private industry. Especially with computer aid the use of project management techniques is invaluable. Ragsdale (2001:699-700) proposes that while spreadsheets can be used to track and manage projects, specialized project management software can greatly simplify many of these tasks. One of the most popular project management tools is Microsoft Project.

2.9. Heuristics

In the absence of exact methods (OR) to solutions we usually resort to heuristics. Murty (1995:410-411) gives the reasons and desirability of heuristics as:

> Heuristic methods are as old as decision-making itself. Until 1950s when computers became available and machine computation became possible, inelegant but effective heuristics were the only methods used to tackle large scale decision-making. In operations research the term heuristic is often applied

to methods that are based on intuitive and plausible arguments likely to lead to reasonable solutions but are not guaranteed to do so. They are methods for the problem under study, based upon rules of thumb, common sense, or adaptations of exact methods for simpler models. They are methods used to find reasonable solutions to problems that are hard to solve exactly. In optimization in particular, a heuristic method refers to a practical and quick method based on strategies that are likely (but not guaranteed) to lead to a solution that is approximately optimal or near optimal. Thus, heuristic methods can, but do not guarantee the finding of an optimum solution; although good heuristic methods in principle determine the best solution obtainable within the allowed time.

But if it does not guarantee optimality why use heuristics? Daellenbach, George, and McNickle (1983:647) argue that a particular heuristic is followed because it promises, intuitively or from experience, to help in the search for an acceptable solution, and if in the process a better rule is discovered, then the old one is discarded. So, while heuristics problem solving involves the use of currently accepted rules, it may also involve a search for even better rules to replace them. Many real-world problems are not amenable to direct analytical solution by known mathematical techniques. But even where it is theoretically possible to apply such methods, if the problem is very large, the task of doing so may be impracticable. Similarly, as Taha (1997:4) put it, some mathematical models may be so complex that it is impossible to solve them by any of the available optimization algorithms. In such cases, it may be necessary to abandon the search for the optimal solution and simply seek a good solution using heuristics. The advantage of a heuristic over an exact optimization algorithm is that it is usually much faster to execute.

Luckily, in the 1980s and recently, software packages implementing sophisticated algorithms, and computer systems that can execute them, became very widely available. So, according to Murty (1995:411), now-a-days there is no reason to resort to heuristic methods to solve such problems. However, in the increasingly complex world of modern technology, skill in designing good heuristic methods for problems for which no effective exact algorithms are known, is an essential component in a successful optimization analyst's toolbox (Murty, 1995:449). The development of heuristic methods is being driven by the ever increasing needs for them in many fields. Daellenbach *et al.* (1983:648) highlight the need to resort to this approach by stating, "Rather than mutilate a problem until it conforms to a model for which an efficient solution technique exists, a more acceptable line of attack is to modify the solution procedure to fit the problem. It is in such situations that heuristic approaches are effective." Heuristic methods themselves are not haphazardly developed, but according to Cook and Russell (1989:6), OR models and techniques are sometimes useful in developing heuristic search procedures.

Despite its practicality, as discussed above, one of the major disadvantages of heuristics as identified by Cook and Russell (1989:204) is that "Even though a good heuristic is generally within 10 percent of optimality, the great disadvantage is that the amount of error of using a heuristic is not known. That is, if you use a heuristic that has not been thoroughly tested, you do not know whether your answer is 5, 10, or even 30 percent from the optimal solution." Even though, Simon's observation (as cited in Gowda, 1999:61) that people act in a boundedly rational manner, and satisfice rather than maximize, is well recognized in political scholarship, utilizing such short cuts is not necessarily rational if it leads to suboptimal results and lowers a decision maker's utility. According to Margetts (2003:367), long accepted problems of rational decision-making such as Simon's 'bounded rationality' can be tackled, as computers are used to simulate policy alternatives.

2.10. Some Practical Applications of Operations Research in the Public Sector

In this section the areas of the military, transportation, crime and justice, police units, energy, natural resources, facility location, and land use planning will be cited as some of the many successful applications of OR.

2.10.1. Military Operations Research

Washburn (1994:68) states that military analyses carried out in peacetime are heavy users of the Theory of Probability, since many things about warfare are unknown or unknowable in the absence of the thing itself. The goals of warfare are multiple, so military analysts are often found groping for the right measure of effectiveness. The complexity and scale of military operations result in computer simulations of combat being heavily employed. The vital influence of the enemy's tactics often needs to be accounted for, either through Game Theory or Wargaming.

2.10.2. Transportation

Odoni, Rousseau, and Wilson (1994:107; 145) indicate that transportation undoubtedly ranks as one of the areas in which OR is most intensively applied. In the transit area OR techniques are alive and well. They are being used to assist in the planning and operation of many transit networks, and shortest path routes around the world.

2.10.3. Crime and Justice

Swersey (1994:201) confirms that the application of OR in mathematical and statistical modeling, to crime, justice, and law enforcement has been an activity of long standing, and one that has benefited both OR and criminal justice practice over the years. Swersey (1994:252) further states that, systematic quantitative thinking by OR approaches to problem solving has been very effective in helping to improve the administration of criminal justice, and it is likely that this effort will continue.

2.10.4. Deployment of Police, Fire, and Emergency Medical Units

In the 1960s operations researchers began studying the deployment of emergency services and since then a very large body of OR literature has emerged. Police, fire, and emergency medical systems are all concerned with improving public safety, and share the common objective of responding to citizen calls for assistance as quickly as possible to reduce loss of life and injury. In each system, the primary problem is to decide the number of land locations of emergency units, and which unit or units to dispatch to an incoming call for service (Swersey, 1994:151).

2.10.5. Energy/Environmental Policy

World supply disruptions during the 1970s, deregulation of energy markets during the 1980s, and heightened environmental concerns during the 1990s have left us with a rich legacy of public sector applications of OR to energy sector issues. Moreover, the emergence of climate change as a critical global environmental concern and the unanticipated and unwanted experience with Desert Shield and Desert Storm ensure that energy/environmental policy will continue to be a rich and diverse OR application area (Weyant, 1994:263).

2.10.6. Managing Natural Resources

At the United Nations Conference on Environment and Development (UNCED) it was acknowledged that: "There is a need for countries to find a balance between the economic and social demands on the world's ecosystem and the need to conserve the natural resources on which the economic and social systems depend. This balance has been termed sustainable development" (Department of Environmental Affairs and Tourism, 2002:3).

(Golden & Wasil, 1994:289) further elaborate that "Flood or drought. Overpopulated or endangered. Harvest or cut back. Too much or too little. The myriad of problems encountered in the management of fish, forests, wildlife, and water are essentially dichotomous and interrelated, and proposed solutions have far-reaching economic, social, and political consequences."

According to Golden and Wasil (1994:314), it is interesting to note that OR models have been applied to natural resource problems that have very different ecological or geographical scales. Some examples follow:

a) *Fish*

According to Golden and Wasil (1994:296), the use of mathematical methods to model fisheries began in the mid to late 1950s to predict the number of recruits (that is, the number of new fish that become vulnerable to fishing in a given season) that will be produced by a population for any given stock size.

b) *Water*

According to Golden and Wasil (1994:338), a wide variety of powerful OR methods (for example, linear programming, non-linear programming, dynamic programming, and simulation) have been used to model and solve important water resource management problems such as operating a multipurpose, multireservoir water system, estimating freshwater inflow needs for estuaries and bays, evaluating investment alternatives in a water supply system, selecting, designing, and managing irrigation methods, expanding water supply capacity, and maximizing benefits in a hydroelectric power system. Operations research methods have been applied to hundreds of problems in both developed countries and less developed countries.

c) Forestry

According to Paull and Walter (as cited in Golden & Wasil, 1994:313), there has been a long and successful association between OR models and problems in forestry that goes back to the mid 1950s. One of the earliest applications of an OR method to a forestry problem was the use of linear programming to solve the paper trim problem, that is, the problem of how to best cut rolls from a machine into sizes that are demanded by customers.

An interactive, video-based training device known as VISION simulates the stem cutting decisions that workers face on the floor of the forest. VISION has optimizing capabilities: a dynamic programming model embedded within the software finds the optimal cutting decision for each stem worker's cutting decision. In this way, VISION serves as both a training device and a decision support system (Golden & Wasil, 1994:314).

d) Wildlife management

According to Golden and Wasil (1994:330-331), the use of mathematical models in wildlife management dates back to the 1920s. However, since the 1970s, standard OR techniques, including simulation, linear programming, and decision analysis, have been applied regularly to wild life management problems.

2.10.7. Facility Location

Lotfi and Pegels (1996:139) point out that facilities or plant layout analysis is concerned with the development of a plan to locate facilities, equipment, and departments in the best location within a specified area such as the floor of a building, a warehouse or a plant. The criterion used to determine the best solution is usually the transportation cost to move inventory, supplies or people between the various locations. Instead of transportation cost we can also use number of trips, travel costs or travel time.

2.10.8. Land-use Planning

According to Rardin (1998:59-61), no public-sector problem involves more conflict between different interests and perspectives than land use planning. A multiple approach can be adopted to construct a plan controlling the use of undeveloped land. For example analysts can employ the following criteria for land use planning.

a) *Compatibility*: an index of the compatibility between each possible use in a region and the existing uses in and around the region;
b) *Transportation*: the time incurred in making trips generated by the land use to/from major transit and auto links;
c) *Tax load*: the ratio of added annual operating cost for government services associated with the use versus increase in the property tax assessment base;
d) *Environmental impact*: the relative degradation of the environment resulting from the land use; and
e) *Facilities*: the capital costs of schools and other community facilities to support the land use.

2.10.9. Selected Countries Applications

There is a clear indication that the public sector is a major employer of labor and a high consumer of a country's resources. Pinkus and Dixson (1981:1) show that in the United States in the early 1980s combined local, county and state governments employed around 12 million people and provided goods and services to a total value of over $350 billion a year. In comparison, General Motors Corporation, the largest industrial employer in the United States in the 1980s, employed about 800,000 people and had sales of approximately $66 billion a year. This resource usage in both sectors is far from comparable. Moreover, governments are getting bigger as population expands and demand for public services grows. This phenomenon makes it imperative for the public sector officials to employ the most advanced OR techniques aided by DSS in their administration for the required service delivery.

The OR Society (2001) lists OR groupings on an international and country level:

i) *International Groupings of Operational Research Societies.*

ALIO— Latin-Iberoamerican Society for Operational Research

APORS— Association of Asian-Pacific Operational Research Societies within IFORS

EURO— Association of European Operational Research Societies within IFORS

IFORS—International Federation of Operational Research Societies

AGIFORS—Airline Group of the International Federation of Operational Research Societies

According to the International Federation of Operational Research Societies (2004), IFORS is an umbrella organization comprising the national OR societies of over forty-five countries from four geographical groupings: Asia Pacific, Europe, North America, and South America. Total membership is over 25,000 people.

IFORS's mission is to promote OR as an academic discipline and a profession.

ii) Operational Research Societies by Country

Some of the countries that have OR societies are as shown in Table II-2.

Argentina	Germany	Poland
Australia	Greece	Portugal
Austria	Hungary	Singapore
Belgium	Iceland	Slovak Republic
Brazil	India	South Africa
Canada	Ireland	Spain
China	Israel	Sweden
Croatia	Italy	Switzerland
Czech Republic	Japan	Turkey
Denmark	New Zealand	United Kingdom
Egypt	Netherlands	United States
Finland	Norway	Yugoslavia
France		

Table II-2. Some of the countries which have OR societies.

Source: OR Society (2001).

Regarding the application of DSS and models the researcher visited two organizations in South Africa and referred to the literature about Egypt, New Zealand, and Norway.

a) South Africa

The levels of development of South Africa and Eritrea are incomparable; hence, a comparative study is not appropriate. However, for further observation and insight about their application of DSS, the researcher visited the Infruitec in Stellenbosch, and the Department of Agriculture of the Western Cape.

i) Infruitech

The Infruitech (Institute for Fruit and Technology) of Stellenbosch has developed a model called General Nonlinear Dynamic Matrix Model which is written in Visual Basic created in Excel. It is a model developed by the integration of different disciplines and mostly helps to decide on the best cultivar in the environment. Its objective is to help improve the quantity and quality of a product, to control influences, and in general to find the equilibrium of a system.

The model incorporates knowledge from the disciplines of social studies, mathematics, physics, vector algebra, chemistry, economics, management, and statistics. It also includes linear programming, dynamic programming, and simulation techniques. This indicates that multidisciplinarity is the best approach to any problem solving. Among others, this model has been applied to study the effect of transaction costs on the decisions of cattle owners in Namibia.

ii) Department of Agriculture of the Western Cape

The Department used a CGE (computable General equilibrium) model to provide a quantitative analysis of the direct and indirect effects of a land tax in the Western Cape. In this Department the researcher was informed that the University of Natal has developed the following software: Fodel, BeefFlo, SheepFlo, DairyFlo, Ryegrass, Feedlot, CashFlo, Pricegen, WinFeed (for food mix) and these are being applied in the Department of Agriculture of KwaZulu-Natal for growing sufficient grass and preparing the required amount of animal food-mix, in order to obtain satisfactory animal products.

b) Egypt

According to the Institute for Development Policy and Management (1998), the increasing cost of, and government subsidy to, electricity generation in Egypt were continuously enlarging the country's balance of payments deficit and adding to public sector debt. To help address this issue, the Information and Decision Support Centre (IDSC) developed a decision support system for the Ministry of Electricity which was intended to:

- assess the impact of tariff changes on different income groups;
- provide statistical data on power and energy generation;
- provide statistical data on the distribution and consumption of electricity; and
- assist decision-making about the pricing and management of loans within the electricity sector.

c) New Zealand

According to Foulds and Thachenkary (2001), FleetManager is a successful milk tanker routing DSS that has generated a spectrum of benefits for the Westland Dairy Company in New Zealand. Much of the benefit is derived from the characteristics and attributes of a classic DSS that supports, but does not replace, the decision-maker. It does not try to provide the 'answers,' nor does it impose a predefined sequence of analysis. It supports semi-structured decisions where parts of the analysis can be systematized for the computer, but where the decision-maker's insight and judgment are improved.

Foulds and Thachenkary (2001) further state that the DSS combine modeling techniques with database and presentation techniques. It emphasizes ease of use, user-friendliness, user control, and flexibility and adaptability. It supports all phases of decision-making. It interacts with other computer-based systems, mainly with the company mainframe system to download and upload information. The success of FleetManager can be attributed to: a) extensive user participation and involvement, b) an evolutionary approach to system development, c) flexibility and simplicity of system architecture, d) a committed and informed sponsor (the Transport Office manager), e) accessibility and transferability of models and data, f) availability of graphics, and g) clarity of insights resulting from the use of judgmental and analytical models. Good relationships and close collaboration between the potential users and developers enhanced the development and implementation of the system.

d) Norway

According to Golden and Wasil (1994:301), the Norwegian industrial fisheries were faced with a relatively large amount of fishing effort (450 vessels), depressed stocks, and a low sustainable yield. Given these conditions, they set out to study the impact of capacity reduction. In particular they formulated the management problem as a linear program which seeks to maximize profit subject to a variety of constraints concerning fleet capacities, capacities of the Norwegian factories where catch is processed into fish meal and oil, and catch limits. The time horizon is one year, and the model allows for multiple species, different types of boats, and numerous factories. By varying the fleet capacity constraints, the model can examine the impact of capacity reduction in a rather systematic way and find the most profitable fleet structure. Using 1977 data, it was demonstrated that the current fleet's profit is 225 million Norwegian kroner whereas the most profitable fleet has an estimated profit of 185 million kroner. In addition the model reveals that factory processing capacity should be maintained in northern Norway, reduced by 40% in the south, and eliminated entirely from the middle region. These results were presented to the Norwegian Department of Fisheries to help with long-range planning. Despite the fact that the model ignores possible nonlinearities, stochastic effects, and multiple objectives, the model seems to give reasonable answers to vital questions regarding capacity adaptation in industrial fisheries.

2.11. Impediments to Operations Research

As a scientific endeavor to problem solving different authors highlighted the following technical and institutional barriers to successful OR applications.

Loucks, Stedinger and Shamir (as cited in Golden & Wasil, 1994:356) indicate that:

- Successful applications of OR models for policy and planning purposes require an institutional interest and commitment. Also critical to success is the establishment of modeling centers that develop, support, and maintain models;
- Analysts are generally concerned with problem detail, while high-level policy makers are concerned with simplicity and generality. Thus, analysts might use complex models that are difficult for policy makers to understand. A spectrum of models that includes comprehensible and credible models is needed;
- Analysts must be able to communicate technical information, as well as environmental, economic, and social information, in such a way that decision makers can easily assess the impact of these factors on the problem setting;

Rogers and Fiering (as cited in Golden & Wasil, 1994:356) show that:

- For a specific decision problem, the important point is that systems analysis techniques should be able to offer decision makers a number of alternative solutions from which to choose; and
- Consultants who perform systems analysis place too much emphasis on delivering a final model by a specified date. Very little attention is focused on issues that surround

the continuing nature of problems, such as ensuring that the client staff is trained to run the model and interpret its results.

As a remedy to the above mentioned impediments Hilborn (as cited in Golden & Wasil, 1994:356) proposes the following points:

a) In order to be successful, an applied systems analysis effort must be requested by decision makers who have the power to insist that final results will actually be used by management;
b) Closing the gap between analysis and successful implementation requires a considerable amount of time devoted to communication;
c) Models should be easy to explain and easy to understand. Furthermore, models should be easy to defend against technical criticism.

2.12. Chapter Summary

In this chapter the argument has been that OR is a scientific approach to decision-making enabling public officials to allocate scarce resources equitably and in a reasonable manner. The essential characteristics of OR are to examine functional relationships from a systems overview, adapt a planned approach, and uncover new problems for study. Operations research is an interdisciplinary field and it stresses that problems cannot be entirely solved within the area of a single discipline.

Operations research is both science and art. It employs mathematical techniques as well as human judgment and intuition. But too much emphasis on mathematical tools and techniques may severely hamper the usefulness of OR. Good practice in OR means appropriate analytical skills as well as adequate softer skills—teamwork and facilitation.

Moreover, OR assumes a systems viewpoint which is a balanced perspective that allows the optimization of an organization's overall goals as opposed to isolated departments. So OR analysts have to construct models that give not only simplified descriptions of mechanisms, but also which are holistic and that assume important aspects of system structure. Systems thinking considers the context of a problem before breaking it down into component parts.

Operations research is a discipline that consumes high modeling techniques. A model takes relevant features, and neglects less important aspects. They are used in policy analysis to predict the future consequences of current decisions. A model provides insight into the problem, permits experimentation by avoiding expensive and/or dangerous ones, avoids the production of unwanted side products, optimizes some objective, and proposes careful use of resources. Models should be impartial and unbiased representations of the phenomena they are intended to reflect. However, in practice they often incorporate the modeler's biases, and are difficult to decision makers to make use of as appropriate prediction instruments. In this case there may be a danger of poor policy outcomes. For better policy outcomes good model building requires that all essential elements of a physical situation or an organizational problem are captured.

Operations research's optimization models like linear programming, nonlinear programming, dynamic programming, and goal and multiobjective programming, are widely applied in the public sector including in the areas like the military, transportation, crime and justice, police units, energy, natural resources, facility location, and land use planning. Other models such as simulation, forecasting, queuing, and inventory have also gained similar popularity.

Project scheduling is one of the few applications of OR that is widely used among both large and small organizations. Project managers must know how long a specific project will take to finish, what the critical tasks are, and what the probability of completing the project within a given time span is. Large numbers of sequential activities tend to create 'bottlenecks' or critical paths. It is the objective of the PERT/CPM technique to identify the critical path. Management then can apply its efforts to alleviate any delays in the activities that are on the critical path and these ensure that a project will be completed as scheduled.

Not all societal problems are amenable to mathematical solutions. For that matter, OR is not a universal panacea. In the absence of exact methods to solutions we usually resort to heuristics, which is not necessarily rational, it may lead to suboptimal results, and lowers a decision maker's utility. However, a particular heuristic is followed because it promises, intuitively or from experience, to help in the search for an acceptable solution, and if in the process a better rule is discovered, then the old one is discarded.

Successful applications of OR are recorded in the areas of military, transportation, crime and justice, police units, energy, natural resources, facility location, and land use planning. Operations research applications are not without impediments. Technical and institutional barriers are some of the problems encountered in the effort to apply OR in the public sector.

Chapter III

Decision Support Systems

3.1. Introduction

A decision support system is an exciting concept which extends the range of decision problems that OR and MIS can support. In particular, it promises to help decision makers deal with unstructured problems which are often encountered in real-world decision-making.

The next section is devoted to DSS which comprise a major part of the chapter. The subsections amplify the need for DSS in the public sector as an effort to make administrators to comply with the required level of service delivery. Operations research, DSS, and MIS are closely interrelated to the point that DSS are the intersection between MIS and OR. Basically, the incorporation of human judgment and its focus on semi-structured and unstructured problems are distinguishing factors of DSS.

Decision support systems vary according to the support they give, ease of applicability, and price. Here some DSS are identified on the basis of user-friendliness, affordability and relevance to the public sector. In addition, as information and communication technology like the Internet, GIS, and mobile phones, support decision-making, they are included as part of DSS.

Towards the end of the chapter there will be an attempt to indicate the challenges posed to OR and DSS by the complexity of society and nature. Finally, it will be shown that DSS is not growing as fast as promised because of some resistance to change and other impediments.

3.2. Decision Support Systems (DSS) for Effective Decision-Making

According to Dowling and St. Louis (2000), DSS are computer-based systems designed to support decision makers and usually include a database and a model base. They are interactive, flexible, and adaptable that utilize decision rules, models, and the decision maker's own insights, leading to specific, implementabale decisions in solving problems that would not be amenable to OR optimization models per se. Thus, DSS support complex decision-making and increase effectiveness.

Operations research has developed many models that could be useful in supporting decision makers. OR, as pointed out by Camm & Evans (2000: 2), is aided by a diverse collection of computer-based methods and tools for building and solving models, which we refer to as *decision technology*. These methods and tools include spreadsheets, data management, data analysis, special software for implementing management science approaches, and communication tools for linking these together. The marriage of OR and decision technology allows managers to better convert data into information and provides powerful insights for decision-making.

Similarly, according to McGowan and Lombardo (as cited in Swain & White, 1992: 650), a decision support system may be defined as a "Computer information system which provides information as a basis for non-routine, semi-structured decision-making. An example of this type of system is one in which the output information provides various policy options for the agency to consider in its dealings with the public and legislature."

However, DSS are not without limitations and Marakas (1998:6-7) points out some of their limitations. He states that DSS contain only the 'knowledge' they have been given by their designers and possess only the 'skills' associated with their tool set; they do not perform reasoning and do not have creativity, intuition or judgment; and there are no universal products and they are only designed to be useful within a relatively narrow scope of problem-solving scenarios in which case the decision maker is faced with the task of coordinating multiple systems.

3.2.1. The Structure and Need for Decision Support Systems

Cloete stresses the need for DSS by indicating that "The strategic adoption of appropriate electronic decision support, policy implementation and evaluation tools can build managerial capacity in public sectors that do not have such capacity at the moment." One of the primary reasons, as stated by Marakas (1998:89), for a decision maker needing a DSS is because the cognitive process of human decision makers is limited in many ways.

The complexity of public sector problems call for computer based DSS and this complexity makes the application of OR techniques dependent on the electronic DSS. Practically, as Taha (1997:4) puts it, all OR techniques result in computational algorithms that are iterative in nature. This means that the problem is solved in iterations, with each new iteration bringing the solution closer to the optimum. The iterative nature of the algorithms typically gives rise to voluminous and tedious computations. It is thus imperative that these OR algorithms be executed by the computer.

The importance of DSS is acknowledged by Thierauf (1982:26) who states that they incorporate features found in management information systems (MIS), and in mathematical models of OR. They emphasize direct support for managers, especially when the problem structures tend to be semistructured and unstructured. The use of interactive systems and video displays in DSS are examples of this point. Emphasis is placed on helping the manager make decisions rather than on actually making decisions for the manager. This interplay results in a total effort that is greater than the computer operating independently (as in classical MIS), thereby providing synergetic decision-making. Similarly, Marakas (1998:51) indicates that DSS is intended to provide managers only with a focused support for one or more activities within the decision process and not to replace them. Because of this limitation, we must become aware of the nature of the available support a DSS can offer. Then we can see the need to incorporate DSS technology in those problem contexts where it is appropriate

According to Foulds and Thachenkary (2001), many DSS have the basic structure that is illustrated in Figure III.1. Clearly, they could include all appropriate models and their companion solution techniques that may be useful in order to gain insight into the scenario for which the particular DSS is designed. These models and techniques may not necessarily be confined to the classical OR deterministic models such as linear, integer, nonlinear and dynamic programming. They may also draw insight from such areas as queuing, scheduling, inventory and others.

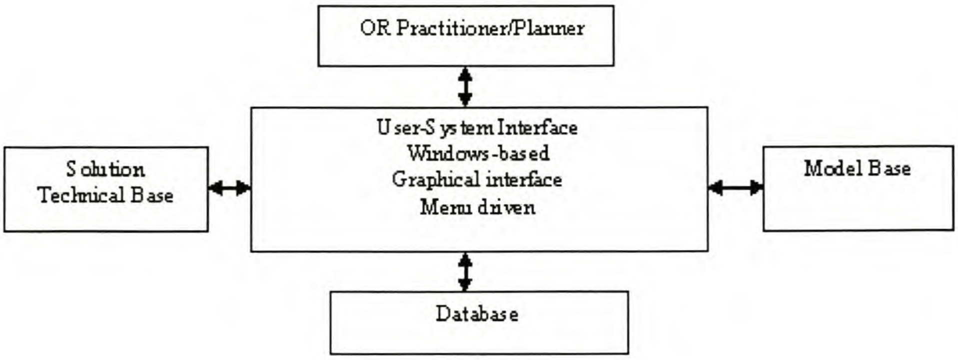


Figure III-1. The structure of a decision support system.
Source: Foulds and Thachenkary (2001).

The model's bases are included in order to be used, as necessary, to solve certain sub-issues or precise questions that arise during the overall analysis of the main scenario. They can be invoked to answer 'what-if' questions, to perform sensitivity analysis, and to provide precise solutions to sub-problems that can be modeled exactly.

However, Foulds and Thachenkary (2001) argue that it must be stressed that any DSS should be much more than just a mere collection of models and solution techniques. Although this DSS can be quite a valuable aid to the implementation of mathematical programming in terms of user friendliness and convenience, it should be only a small part of any DSS. The essence of the DSS is the user-system interface that allows the planners to experiment, input local knowledge and inspiration, deal with unstructured situations, be flexible, and allow for multiple objectives as well as soft (violatable to some degree) constraints.

Usually a computerized decision support system may be needed for various reasons. The common ones are identified by Turban & Aronson (2001:9-10):

- Speedy computations (large numbers of computations and very quickly);
- Increased productivity (saving cost by reducing size of group);
- Technical support (search, store, and transmit from different databases);
- Qualitative support (more alternatives evaluated, check many possible scenarios, and assess diverse impacts quickly);

- Competitive edge (frequent and rapid change of mode of operation, empowerment of employees, enhanced innovation); and
- Overcoming cognitive limits in processing and storage (human mind is limited in its ability to process and store information).

These DSS tools are influencing the way public administrators function their activities and are posing new challenges to management. Cloete emphasizes that in order to improve policy successes and good governance outcomes, it is crucial that the quality of public sector management be improved and kept abreast with time. Globalization processes, especially the impact of the electronic technological revolution makes it imperative that the current management paradigm in the public sector be revised.

One major advantage, as pointed out by Dekker and Van Rijn (1996:104) is that computerized DSS has the ability to evaluate the importance of data, just by evaluating the effect of different parameter values on the outcomes. According to Cook & Russell (1989:693), DSS often provides daily operating decisions and the answers to complex 'what if' questions. This is of great help in getting a good insight into the problem. Another advantage of DSS, continue Dekker and Van Rijn, is the ability to evaluate many alternatives quickly in a rather objective way. This reduces the infighting between various people because each can make a proposal which is evaluated in an objective way.

However, a disadvantage of a strategic DSS as identified by Dekker and Van Rijn (1996:104) is that it requires a central expert to operate it. Since each problem is different and appears only once in a while, expertise in operating such a system rapidly fades away. It is not always easy to model a problem with the models incorporated in such a system. There are many hidden assumptions and thoughtless use may even do more damage than good. Hence, the DSS should be very user-friendly and their models should be robust, flexible and transparent to the user. The development DSS is not an easy task since it requires both expertise in the problem area (maintenance), in OR models and in computer science. Moreover, there is a high obsolescence rate in computers, especially at the personal computer level.

Operations research primarily aims at improving the effectiveness and the efficiency of the processes of decision-making that occur in every segment of society including industry, banking, agriculture, government, and politics. The distinctive feature about OR is that it commonly makes use of optimization models. From the very start of the 1980s these models have been increasingly 'cloaked in user-friendly wrappings', the so called DSS (Van Beek et al., 1996:269). According to Marakas (1998:67), optimization is considered a rational decision-making behavior that suggests that the decision maker will choose the alternative that is clearly the best one providing the best overall value and outcome. For the rational decision, by selecting the best alternative, the decision maker has to be empowered by both OR techniques and DSS.

3.2.2. Distinguishing DSS from OR and MIS

DSS, MIS, and OR are related as shown in Table III-1. DSS focus more on semistructured and unstructured problems, while the focus of MIS is on well-structured problems.

During the 1970s and into the 1980s, as observed by Cook and Russell (1989:6), OR has become increasingly concerned with the interface with MIS. Computerized data bases play a vital role in supporting OR models as well as in everyday decision-making. As depicted in Figure III-2 the marriage of OR and MIS has resulted in a special kind of information system called a decision support system (DSS). This type of system holds great promise for the enhancement of the decision-making process at all levels of management.

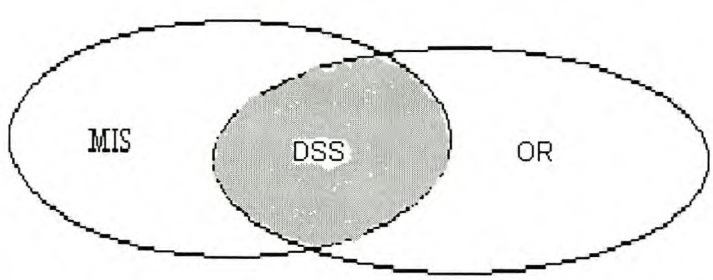


Figure III-2. The MIS-OR interface.
Source: Cook and Russell (1989:695).

There has been much discussion in the OR literature whether DSS is really unique or just a new acronym for MIS. However, DSS can be thought of as the point where the MIS discipline and the OR discipline meet. DSS must have the attributes of an MIS as well as the decision-making or decision-aiding capability of OR models. The incorporation of the human judgment process also further distinguishes DSS from other information systems (Cook & Russell, 1989:695; 700). Turban & Aronson (2001:110-111) further distinguish

MIS and DSS by noting that "MIS can be viewed as an information system application that can generate standard and exception reports and summaries, provide answers to queries, and help in monitoring and tracking… A DSS on the other hand, is basically a problem-solving tool and is often used to address ad hoc and unexpected problems."

The role of MIS and DSS in terms of their aid to solve structured and unstructured problems is distinguished in Table III-1.

Type of system	Principal type of problems structure	Decision-making capability
DSS	Semistructured and unstructured (includes well structured)	Manager/machine interface where the manager retains control for synergistic decision making
MIS	Well-structured	.New information produced via analytical techniques for specific decision-making situations. .Summarization of information in the form of control reports for periodic decision-making. .Collection and tabulation of data using transactional processing for possible decision-making.

Table III-1 Relationship of DSS and management information systems.
Source: Thierauf (1982:27).

De Cock and Sinclair (1987:2) show that problems encountered by managers can be classified as either 'structured' or 'unstructured' problems. A structured problem is one of which the solution process can be fully automated and which thereafter does not require any managerial intervention. An unstructured problem, on the other hand, is one which cannot be automated in this way, and must be solved through intuitive reasoning by managers. Between these two extremes lie semi-structured problems, i.e. problems that have parts which are structured and others which are not. Although DSS focus on the semistructured and unstructured problems, according to Turban & Aronson (2001:41), this does not preclude them using optimization because often a problem can be decomposed into subproblems, some of which are structured enough for applying optimization. In addition, optimization can be combined with simulation for the solution of complex problems.

Similarly, Swain and White (1992:650), point out that DSS are designed to deal with unprogrammed decisions facing mid-level to upper managers and professional staff. They are extremely user-friendly, requiring only a little knowledge of computer use, and they are flexible enough to support different decision-making styles of a variety of users. While they may obtain data from MIS, other data are supplied by the user in an interactive mode. They can incorporate a wide range of OR techniques. With these features in place, a DSS can handle large amounts of heterogeneous data, offer modeling and analytical capabilities for maximizing and minimizing objectives within given constraints, and provide a variety of reports and graphics designed by the user. They support human decision-making by making it easier for the user to manipulate data, develop models, and build scenarios. In this way, they are supposed to improve the quality of decision-making, especially when there are multiple objectives and multiple tradeoffs involved.

As an illustration of practical application Pierskalla and Brailer (1994:479-480) show that MIS are usually required to implement OR models in health care management. In combination with decision and model-based support systems, MIS have the potential to improve decision-making responsiveness, quality of patient care, and productivity. Quality of care improvements can result from reduced waiting time for physicians' orders to be carried out and results to become available, elimination of unnecessary services, reduction of errors, and increased provider and patient satisfaction. Productivity is improved by appropriate data availability for decisions about staffing patterns, scheduling, use of equipment and materials, and by the elimination of redundant systems and actions. According to Cook and Russell (1989:693), "DSS goes beyond aiding the decision-making process by merely providing the decision maker with timely and relevant information.... In addition to the standard reports and inquiries that typically are produced by conventional systems, DSS often provide daily operating decisions and the answers to complex what-if questions."

Furthermore, as shown in Table III-2, Keen and Scott-Morton (as cited in Turban & Aronson, 2001:41) MIS, OR, and DSS are distinguished along main impact, main payoff, relevance for managers, and their application.

	Main impact	Main payoff	Relevance for managers	Application
MIS	On structured tasks, where standard operating procedures can be reliably predefined	Improving efficiency by replacing clerical personnel or increasing productivity	Indirect (by providing reports and access to data).	Routine and done periodically
OR	On structured problems (rather than tasks) in which the objective data and constraints can be prespecified	Generating better solutions for general categories of problems	Provision of detailed recommendations and new methods of handling complex problems	No routine, as needed
DSS	On decisions in which there is sufficient structure for computer and analytic aids to be of value but where the manager's judgment is essential	Extending the range and capability of manager's decision process to help effectiveness.	Creation of a supportive tool under their control that does not automate decision process or impose solutions	No routine, as needed

Table III-2 Distinguishing MIS, OR, and DSS

Source: Adapted from Keen and Scott-Morton (cited in Turban & Aronson, 2001:41).

3.2.3. Some User-friendly Decision Support Systems

Turban & Aronson (2001:41) observe that inexpensive, user-friendly optimization software packages for conducting analysis for many structured situation are readily available. The limitation of optimization is that it works only if the problem is structured and, for the most part, deterministic (nonrandom). If reality differs significantly from the assumptions used in developing the model, optimization cannot be used. Two advantages of optimization are that the expressions that represent the problem are based in algebraic notation and that there is readily available, robust optimization software (e.g. Lindo, Lingo) some including spreadsheet add-ins (e.g. Standard and Premium Solver, and What's*B*est). A disadvantage is that a particular problem may not fit the framework of optimization or that it is too complex to be solved to optimality. In this case, we can sometimes use heuristics. These software are mainly used to solve subproblems, that is the technical aspect of the problems.

Government organizations, at all levels, are challenged to respond to constituent and employee demands for additional and more effective services. Regulatory requirements dictate upgrade and integration of systems to provide a high level of accountability to taxpayers. Administrators need more financial reporting information to support decision-making. Recruiting and retaining highly skilled staff can also be a challenge. Today's public sector environment requires government organizations to meet all of these challenges, while also contending with reduced budgets and the rapid pace of technological change. In short, government organizations must find ways to do more with less money, and quickly.

Decision support software can help government organizations meet these demands and prepare for tomorrow's challenges through streamlining, standardizing and improving business processes to increase productivity, reduce costs, and deliver improved service, accountability and transparency to constituents.

To help achieve the above mentioned objectives there are many software available in the market. The point is to find one that suits the specific purpose. According to Cloete (2002b), the criteria for comparing and selecting decision support tools could include simplicity, cost, hardware requirements, access and maintenance, visual images, specificity, versatility (flexibility), compatibility, transparency and scientific rigor.

The following is a partial list taken from Cloete (2002b) which can be applicable to Eritrea, selected on the basis of affordability (cost) and user-friendliness. See Table III-3.

Software	Cost	Requirement and Comments
Criterion-decision http://www.infoharvest.com	US$695	Very useful qualitative and quantitative Multiple criteria decision analysis (MCDA) decision support package. Comprehensive, user-friendly and flexible. One of the best on the market in its field.
Decideright http://www.skyhunter.com/dr.htm	$110	Very simple entry level, bottom of the market utility qualitative MCDA decision support program, extremely user-friendly, color coded presentations, automatic report writing and visual presentation facilities. Restricted capabilities.
Decision Explorer http://www.banxia.com standard single license (full package with manuals)	£295	Excellent qualitative problem identification and structuring program to identify causal relationships among variables. Effective for creating a visual map of a complex system with varying relationships at different levels. Best used in preparation for MCDA exercises.
DecisionPro http://www.vanguardsw.com DecisionPro 4.0 Personal DecisionPro 4.0 Professional DecisionPro 4.0 Developer	 US $495 US $795 US $995	Very powerful MCDA program with many separate functions in the field of risk assessment, forecasting, etc.
Simul8 http://www.visualt.com Simul8 Standard Simul8 Professional	 US $995 US $995	Very user-friendly. An integrated environment for working with simulation models. The powerful language and model visualization capabilities enable you to create the accurate, flexible and robust simulations you need in less time
Stradspan http://www.binternet.com/~stradspan	£360-576	Excellent qualitative problem identification and structuring program to identify causal relationships among variables. Effective for creating a visual map of a complex system with varying relationships at different levels. Best use in preparation for MCDA exercise

Table III-3. Some user-friendly decision support systems.
Source: Cloete (2002b).

Furthermore, some easily affordable and user-friendly software are discussed below and their application is demonstrated in Chapter IV. Microsoft Project, though its application not demonstrated, is specifically discussed here because of its immediate need in Eritrea.

a) Premium Solver Platform Version 5.5

The Premium Solver Platform is a spreadsheet optimization product that is an upwardly compatible extension of the standard Microsoft Excel Solver, with capacity to solve much larger problems—up to 2,000 variables—at speeds five to twenty times faster than the standard Solver. If you want to solve optimization problems larger than these limits, or if you want even faster solution times of problems within these limits, you can expand the Premium Solver Platform with field-installable Solver engines -- currently up to 100,000 decision variables for quadratic and nonlinear problems, and up to 200,000 variables for linear programming problems It is priced at $995 (Simul8 Corporation. 2004).

b) What'sBest

What's*Best* is an add-in to Excel that allows optimization models to be built in a free form layout within the spreadsheet environment. What's*Best* links spreadsheet software, the preferred modeling tool of business, with the power of linear, nonlinear, and integer programming optimizer techniques. It incorporates numerous enhancements for maximum speed and robustness (Lindo Systems).

For nonlinear programming models, the primary underlying technique used by What's*Best*'s optional nonlinear solver is based upon a Generalized Reduced Gradient (GRG) algorithm. What's*Best* will automatically select the solution approach that appears best suited to the specific model at hand. The solution approach is dynamically adjusted during the solution process based upon the model's behavior. With What's*Best*, you never have to specify whether to use the linear or nonlinear solver. Based upon the model's structure, What's*Best* automatically selects the appropriate solver and intelligently adjusts internal parameters.

Prices are What'sBest Commercial $495, Professional $995, Industrial $2,995, and Extended $4,995.

c) V.I.S.A (Visual Interactive Sensitivity Analysis)

According to Frontline systems, V.I.S.A for Windows is a decision support tool that helps compare alternative strategies or options against multiple criteria. The name, V.I.S.A (Visual Interactive Sensitivity Analysis) reflects the principle design objective - to facilitate modeling and analysis in a way that is both visual and interactive, leading to improved understanding, better communication, and consequently, better considered decisions.

The many new features, including the possibility to incorporate video or graphics depicting options, enhance the power of V.I.S.A to help decide what is best for organizations. It is used for individual or to facilitate group decision-making.

V.I.S.A 's Features include:

- The ability to draw/change the criteria hierarchy on screen using the mouse;
- No limit on the size or complexity of the criteria hierarchy or the number of options/strategies;
- Interactive input of weights and scores using bar charts or thermometer scales or numerical input;
- The ability to view criteria weights / option scores / option profiles at multiple levels of the hierarchy at the same time (each in its own window); and
- Sensitivity graphs showing the effect on options of changing the weight of a selected criterion.

V.I.S.A is priced at $199.

d) NeuNet Pro 2.3

The CorMac Technologies indicate that if a bank manager wants to decide which customers will qualify for a loan he can use a DSS called NeuNet Pro 2.3 which depends on a completed application form. A NeuNet Pro 2.3 (neural network) is a software (or hardware) simulation of a biological brain (sometimes called Artificial Neural Network or 'ANN'). The purpose of a neural network is to learn to recognize patterns in data. Once the neural network has been trained on samples of data, it can make predictions by detecting similar patterns in future data. As most real-life problems are non-linear in nature, bank loans have many non-linearities, and are subject to millions of possible inputs patterns.

If we had a large number of loan applications as input, along with the manager's decision as output, a neural network could be 'trained' on these patterns. The inner workings of the neural network have enough mathematical sophistication to reasonably simulate the expert's intuition. Neural networks are able to detect similarities in inputs, even though a particular input may never have been seen previously. This property allows for excellent interpolation capabilities, especially when the input data is noisy (not exact). Neural networks may be used as a direct substitute for autocorrelation, multivariable regression, linear regression, trigonometric and other regression techniques.

Its price begins at $99 for the first level (limited use) and increases with demands for higher levels.

e) Microsoft Project 2003

According to J&R Electronics (2004), Microsoft Project 2003 helps to manage a project and a set of workgroups independently or across a department, more easily. This project-management package lets you build enterprise-wide management solutions. You can visualize the most complex plans by splitting a project into manageable steps to see in detail how the tasks are related, which are most important to your overall schedule, where bottlenecks will occur, and how much the whole project will cost.

Microsoft Project 2003 is a powerful new tool for project leaders who need to manage projects independently. Among others, it has the following benefits:

- Organize your work more effectively with new scheduling tools—Track schedule and resource changes to your project plans quickly;
- New display options lets you show individuals the project information they need to review;
- Increase your impact at work and create better presentations to print compelling and succinct copies of schedules and goals; and
- Move information easily between Project 2003 and other Microsoft Office programs, such as Excel.

Similarly, according to Schwalbe (2000:405-411), Microsoft project 98 assists users with different aspects of all nine project management knowledge areas (project integration management, scope, time, costs, quality, human resources, communications, risk, and procurement management). Microsoft project is by far the most used computerized project management tool. Managers use it for project control and tracking, detailed scheduling, early project planning, communication, reporting, high-level planning, Gantt CPM, and PERT.

Microsoft project uses an underlying relational database (Microsoft Project Database). There are different versions of The Microsoft Project (98, 2002, and 2003) out of which the Microsoft Project Professional 2003 is priced at $939.

3.2.4. Other Information and Communication Technologies for Supporting Decision-Making

Communication is a vital element for decision support. Without communication, there is no collaboration. Individual decision makers must communicate, among others, with colleagues, experts, government agencies, customers, business partners. They also need data and information (and knowledge) from many locations around the globe (Turban & Aronson, 200:264-265). Thierauf (1982:5) points out that there is a growing awareness that accurate and timely information is a vital resource and that an effective information system is a means of providing the needed information. According to the World Bank Group (2002:vii), developing countries face opportunity costs if they delay greater access to and use of information infrastructure and information technology, which together make up information and communication technologies (ICT). Similarly, Cloete argues that in the face of fast diminishing resources, as a result of over-exploitation and mismanagement, information technology can be used very effectively as development instrument to increase the effectiveness and efficiency of development programs of developing countries which are increasingly unable to meet the fast rising expectations of their populations.

The World Bank group further indicates that information and communication technologies:

- Are the key input to economic development and growth;
- Offer opportunities for global integration while retaining the identity of traditional societies;
- Can increase the economic and social well-being of poor people, and empower individuals and communities; and
- Enhance the effectiveness, efficiency, and transparency of the public sector (including the delivery of social services).

Generally, as Margetts (2003:367) observes, ICT can have policy impacts in a number of ways. For example, police databases with massive search capacity have long facilitated a move towards more pre-emptive policing; more recently, widespread use of Closed Circuit Television (CCTV), DNA samples offer the potential to revolutionize policing strategies. In addition to the heavy reliance placed upon them in all streams of government activity, ICT, particularly in the area of law and order, open new policy windows. The electronic tagging of prisoners has made possible new policies, such as the early release of prisoners and curfew orders, which are forcing policy makers to re-evaluate traditional notions of punishment.

Another area in which ICT can have a significant impact is the way democracy is practiced as put by Jankowski and Nyerges (2001). They state that:

> One of the fundamental freedoms in a democratic society is the right of a citizen to know and participate in a decision situation when decisions about valued concerns are being made that affect the welfare of those people and places they live in. This is particularly true when those situations involve public or public-private problems, and the impacts occur to community at local, state, regional, national, and global scales. It seems that representative democracy is being challenged in a way by modern communications technology. With direct access to information communication technology comes an impression that direct democracy is better due to closer ties to information. The Internet is at the core of a change in getting access to information in a timely manner. Getting access to wireless, Internet communications technology that is on the verge of a substantial expansion will likely fuel the frustration in decision situations.

The Internet, mobile phones, and GIS increase decision-making capability of individuals, businesses and governments in a transparent and cost effective way. These potential usefulness are discussed below.

a) The Internet

According to CAFRAD (2001)—African Training and Research Centre in Administration for Development—the Internet and related technologies are transforming the world we live in. They are expanding their influence on the way individuals, not-for-profit bodies, businesses and governments communicate and operate. Margetts (2003:374) foresees that with more developments towards a Web-based opening up of government agencies we might see a new 'open book' governance, with citizens more involved in public decisions and new forms of public accountability.

In the context of a highly controversial use, as indicated by Märker, Hagedorn, Morgenstern, & Trénel, Internet groupware was used to support a public discussion which shows that the potential of the Internet to integrate public knowledge into decision-making process. Ideally, argumentative public deliberation process generates knowledge of different kinds, namely factual knowledge (*what*?), explanatory knowledge (*why*?), deontic knowledge (*should*?), instrumental knowledge (*how*?), and conceptual knowledge (*definitions*).

According to Märker, *et al.*, imbalances between the information available to the citizens and to the government can be reduced and the citizens can get the opportunity to participate competently because of the information from the Internet.

The Internet has made possible e-government to take place. The Pacific Council on International Policy (2002) broadly defines e-government as the use of ICT to promote more efficient and effective government, facilitate more accessible government services, allow greater public access to information, and make government more accountable to citizens. E-government might involve delivering services via the Internet, telephone, community centers (self-service or facilitated by others), wireless devices or other communications systems.

According to the Information Services Division, National Library Board (2002), UNPAN identifies five principles that should guide e-government initiatives:

- Building services around citizens' choices;
- Making government and its services more accessible
- Social inclusion;
- Providing information responsibly; and
- Using IT and human resources effectively and efficiently

From these principles, UNPAN concludes that e-government is "A permanent commitment by government to improve the relationship between the private citizen and the public sector through enhanced, cost-effective and efficient delivery of services, information and knowledge. It is the practical realization of the best that government has to offer".

Despite its widespread unprecedented creation of opportunities to access information and improve decisions the Internet has many new problems. Seeking information on the Internet is often time-consuming. Internet users, regardless of their role, background or knowledge, can experience confusion and anxiety because of the virtually unlimited amount of information available, information that is often poorly organized and of highly variable quality and relevance. The Internet can also lead to conflict among decision-makers if they have access to different and contradictory information. A person's health might even be worsened if inaccurate information found on the Internet were used by decision-makers. Nevertheless, the advantages gained much outweigh the problems.

b) Mobile phones

According to Riseley (2001), mobile phones are fast becoming an integral part of modern society, and are further developing by bringing access to email, internet and other services. The growth of mobile phones has brought social and economic benefits including flexible work and life patterns, personal safety, and better access to emergency services. People will value information on mobile phones that leads to better decision-making—saving them time, money or hassle. A new level of mobile interactivity is decision support—offering mobile information that helps people make better decisions while on the move. Companies that already offer products or services, such as banks, airlines, and car manufacturers, will dominate these applications.

Moreover, the Internet and mobile phones are simplifying much of the data collection process, making it possible to have wide coverage of a population, and to reach remote areas. The old obstacles of record management and paper filing are fading away (World Bank Group, 2002:61).

c) GIS

Koch (1999) gives a description relating OR and GIS by stating: "Marry linear programming to simulation modeling. Combine the perspectives of locational analysis and the general constructs of social theory. Meld time and distance as equal variables. In fact, throw in all the data variables you want. Then crunch the numbers in a manner that yields a solution page whose results are not only robust but also intuitively comprehensive, graphic and clear." This implies that Geographic Information Systems (GIS) have become significant decision-making tools as their capabilities have been enhanced. The literature concerning GIS contains an expansive array of public sector applications. This is due to the fact that geography (physical, social and political) has a profound impact on the activities of government agencies (Garson, 1999: 220-221).

According to Stevens and Thompson (1996), *Geographic Information Systems,* can be defined as contemporary computer-based tools for working with spatial data for phenomena on, above or below the earth's surface. Data, information and knowledge have to be differentiated in the GIS context: *Information* is derived (using spatial analytical tools) from the individual *data* elements in a spatial database, whereas *knowledge* is the understanding of possible consequences based on the information derived from data and a specific line of reasoning (a spatial decision model) followed by the GIS user (see Figure III-3).

Figure III-3. From data to information to knowledge.

Source: Stevens and Thompson (1996).

All transformations of data into information and then into knowledge have to be done with an aim in mind, which is the search for an optimal solution to a specific spatial problem.

Furthermore, the use of GIS as an ideal tool to analyze and solve multiple criteria problems, is listed by Márkus:

- GIS databases combine spatial and non-spatial information;

- A GIS generally has ideal data viewing capabilities - it allows for efficient and effective visual examinations of solutions;
- A GIS generally allows users to interactively modify solutions to perform sensitivity analysis;
- A GIS, by definition, should also contain spatial query and analytical capabilities such as measurement of area, distance measurement, overlay capability, corridor analysis;
- GIS has the potential to become a very powerful tool to assist in multiple criteria spatial decision-making and conflict resolution; and
- Some GIS have already integrated multiple criteria methods with reasonable success.

An example of GIS application is cited by The World Bank Group (2002:61). GIS, Internet, and telecommunication together can be a powerful force for coordinating health care delivery in areas where disease is rampant and communications are poor. Furthermore, Stevens and Thompson (1996) identify that regional planning problems in developing countries belong mostly, if not entirely, to ill- or semi-structured problems, and because of this GIS technology will have a much larger role in the search for solutions to regional problems. To tackle these ill-defined or semi-structured spatial problems, academics and practitioners have built upon GIS and developed spatial DSS .

In relation to these spatial DSS, including group decision-making, as indicated by Jankowski and Nyerges (2001), is growing in importance as more and more people with concerns about environmental, land use, natural resource, and transportation issues believe that those who are impacted by decisions should be a part of the process. Many geographical decision problems are viewed as unstructured and laden with locational conflict because their solutions are formed through the participation of multiple stakeholders with varying stakeholder values.

The application of GIS is expanding as it is being melded with other computer technologies, including GPS hardware and software, spreadsheets, and CAD software (Armstrong and Densham). In addition, according to Zhao and Lin (2002), Web GIS has developed into a mature Internet mapping and spatial analysis toolkit. Internet together with Web GIS launches a channel to get mass participation in a spatial referenced decision-making. However, as indicated by Márkus the lack of GIS knowledge to effectively aid decision evaluation and policy formulation has often led to the empowering of selected sectors of society. As a result, GIS tends to divert the process of decision-making away from decision makers and into the hands of GIS analysts. To stop this process, GIS education for decision makers is an urgent need.

3.3. Group Decision Support Systems (GDSS)

The move towards GDSS stems from awareness that decision-making is often a group phenomenon, and thus computer support for communication and the integration of multiple inputs in DSS is required. The system consists of a number of different tools that are intended to assist in aspects of the group decision-making process. There is support for including brainstorming activity, for ranking alternative choices and voting on them, and for preserving anonymity (Bannon).

GDSS are designed to support group decision-making through specialized software, hardware and decision support tools. DeSanctis and Gallupe (as cited in Rees, J. and Koehler) defined GDSS as "A combination of computer, communications and decision technologies working in tandem to provide support for problem identification, formulation and solution generation during group meetings." Meetings can be either face-to-face (proximate) or computer-mediated (distributed). The meeting time can be same-time (synchronous), or different-time (asynchronous) meetings. Kenis (1995:27-28) indicates that computers until recently, only supported individual work. With the appearance of group support system and especially computer supported cooperative work, group work support on computer (networks) is also envisaged. Computer conferencing technology enables remote meetings, which clearly has a great impact on the situation in which people discuss.

Group decision support systems have been developed in response to the negative effects of traditional meetings. According to Kenis (1995:4-5), different authors have listed the following restricting and dysfunctional issues in face-to-face meetings:

- The hasty formulation of preconceived notions and an inclination to close one's mind to novel ideas often induced by too little time for reflection, leading to speedy decisions before all problem dimensions have been considered;
- A central tendency effect where groups tend to follow a single train of thought;

- A tendency to defend a stand once taken, i.e. winning the argument is more important than reaching a better conclusion;
- The influence of a dominant personality who acts persuasively, especially when no leader is appointed in the group;
- Group pressure for conformity (groupthink) and the implied (spoken or unspoken) threat of sanctions from the more knowledgeable and/or powerful members (evaluation apprehension). The result is that extreme controversial points of views are not expressed or weakened (see Annexure A for its severity);
- The difficulties in getting together a large group of experts because of time restrictions and geographical distances; and
- Groups tend to be more willing to take risks than individuals (diffusion of responsibility—risky shift).

As a response to the above-mentioned negative effects GDSS are designed to have advantages over face-face traditional meetings. Bannon lists the major points as follows:

- People work on the system in parallel, so it is possible to get a lot more ideas into circulation and captured quickly using the system during brainstorming;
- Since the input is anonymous, there is equal opportunity for participation by all at the meeting, unencumbered with power or status differentials;
- The system enables larger group meetings to be effective through control of the process;
- The system permits the group to choose between a variety of techniques;
- The system offers access to external information sources that can be utilized in the group decision process more easily and effectively; and
- The system supports development of an organizational memory, by keeping a record of the inputs of the participants during the meeting, and of the choices made.

Special software like Facilitate.com 8.0 and OptionFinder are available to help groups in their decision-making processes.

Facilitate.com 8.0 provides support to the group decision-making process with tools that facilitate brainstorming, idea generation, organization, prioritization, and action planning. In the meeting room or over the Internet, a decision support system can help you run meetings more effectively, including at different places and different times (Facilitate.com, 2003).

Similarly OptionFinder is an interactive group decision support system that uses a combination of state-of-the-art software and wireless keypads to help meeting participants make better decisions. The keypads allow participants to respond anonymously, thereby encouraging more honest and accurate responses. It includes sophisticated prioritization tools that allow groups quickly and easily to poll through a series of action items, initiatives, or goals (Option Technologies Interactive, 2003).

3.4. Impediments to Decision Support Systems

According to Cook and Russell (1989:703), DSS are scarce. Reasons for the slow growth of DSS include:

a) *Lack of user demand*: there is lack of understanding on the part of user management concerning what they should expect of their information systems. The typical user is often delighted if the data processing professional merely automates the manual system successfully and on time.

b) *Lack of system designer motivation*: if users do not demand more progressive DSS, there is little motivation for the system designer to think creatively.

c) *Lack of system designer expertise*: a lack of modeling quantitative skills on the part of the system designer often eliminates the possibility of designing a progressive DSS. Integrating a linear programming model or a forecasting model into the design of an information system is often not considered, primarily due to the lack of experience of the system designer or project leader.

d) *Reluctance to change*: human beings have a natural reluctance to change. This built-in inertia has resisted the use of structured design and structured programming techniques. It is also resisting the change from traditional transaction processing systems to DSS.

e) *Increased risk of failure*: designing and implementing a DSS typically has a greater risk of failure than do less complex information systems.

3.5. Complexity Theory: Challenges to OR and DSS?

According to Ciliers (1998:1-2):

> The power of technology has opened new possibilities for science. One of the most important scientific tools has always been the analytical method. If something is too complex to be grasped as a whole, it is divided into manageable units which can be analyzed separately and then put together again. However, the study of complex dynamic systems has uncovered a fundamental flaw in the analytic method. A complex system is not constituted merely by the sum of its components, but also by the intricate relationship between these components. In 'cutting up' a stem, the analytical method destroys what it seeks to understand. Fortunately, this does not mean that the investigation of complexity is hopeless. Modeling techniques on powerful computers allow us to simulate the behavior of complex systems without having to understand them. We can do with technology what we cannot do with science....Our technologies have become more powerful than our theories and we are capable of doing things that we do not understand... We can store and retrieve endless bits of information without knowing what they mean.

The mechanical and static view of society and nature is giving way to dynamic and complex approaches. Stacey, Griffin, and Shaw (2000:1) indicate that there is now a growing literature by management thinkers who appeal for insight to developments in the natural sciences of complexity, felt by many to be relevant because they model complex, turbulent systems. These models demonstrate the possibility of order emerging from disorder through processes of spontaneous self-organizing in the absence of any blueprint.

Ciliers (1998:120) conceptualizes that the social system is non-linear and asymmetrical as well. The same piece of information has different effects on different individuals, and small causes can have large effects. The competitive nature of social systems is often regulated by relations of power, ensuring an asymmetrical system of relationships. According to Linstone (1999:244), these dynamic complex systems, like society, exhibit nonlinearity in their course of development, which seem to diminish the power of OR techniques. According to Stacey *et al* (2000:125), complex systems have the internal capacity to change spontaneously in unpredictable ways that cannot be described as optimizing anything. Their creative development cannot be designed, planned or controlled. Characteristics of nonlinear systems, as identified by Linstone, (1999:244) may be:

- Stable, that is, converging to an equilibrium;
- Oscillating stably;
- Chaotic within predictable boundaries; and
- Diverging unstably.

These characteristics of complexity, according to Ciliers (1998:59), give rise to the unfortunate situation, where the ease with which symbols can be made to represent something vanishes. From the perspective of traditional mathematics, these problems of complexity were seen as intractable, but the phenomenal rise in the power of computers has turned attention back to complex issues such as the modeling of natural language, the modeling of human sensory capabilities (e.g. pattern recognition, computer vision), the simulation of higher cognitive processes (reasoning, decision-making) and sophisticated motoric behavior (robotics).

Chaos theory suggests that many of our assumptions about the predictability of events are misplaced. Stacey *et al.* (2000:17-18) emphasize that non-linear holistic ways of understanding phenomena, are held to demonstrate limitations to predictability, thereby challenging the possibility of simple forms of control by humans over both nature and organizations. Stacey *et al.* (2000:123) believe that although short-term developments are predictable, long-term evolution emerges unpredictably. Emergent creative developments can be articulated and understood only as they emerge and cannot be predicted in advance. In addition Jennings and Wattam (1998:311) indicate that:

> Conventionally, in decision-making theory, the lack of predictability is explained by factors such as a lack of information or the limitation of predictive techniques, but a more recent explanation provides different insights. Chaos theory suggests that a whole range of phenomena are inherently unpredictable. As a consequence, to try and foresee the future may be a futile and wasteful activity; we may need to take decisions knowing we can never be sure of the outcomes.

According to Cook and Russell (1989:9), today's human/machine organizations operate under conditions of rapid change and ever-increasing complexity. Good decision-making therefore, requires that management take a broad and flexible view. Accordingly Linstone (1999:252-255) states that at the most fundamental level, complexity science implies the evolution of a significantly different approach to corporate planning to fit a rapidly changing environment, facilitating self-organization and maximizing adaptability. The British Operational Research Society (as cited in Graf, 2002) shows that OR can be used to solve problems which incorporate factors such as complexity, uncertainty, and conflict.

Nevertheless, we are not helpless amidst the complex phenomena of nature. Ciliers (1998:24) indicates that computer technology has opened up new possibilities for the modeling of complex systems. Moreover, of more practical value, Linstone (1999:253-254) proposes the following options regarding handling complexity:

- *Crisis managemen*t: one lesson planners can draw from military planning is to deal with unanticipated situations. Planners traditionally begin with the 'most likely scenario' for the future. In contrast, military officers train by extensive war gaming, confronting many alternative scenarios, none of which they expect to face in the real world. The point is to train the decision maker to react effectively regardless of which actual situation materializes. This training enhances the ability to manage crises by focusing on robustness. We have to prepare for the worst.
- *Experimentation*: the military provides an interesting example of dealing with complex sociotechnical systems. It is 'the lessons learned' process, which focuses on trying out systems operationally in a realistic setting, rapidly gathering the lessons of success or failure, and disseminating that information to all relevant units.
- *Exploiting stability-instability boundaries*: the planner who seeks system stability in the non-linear system can take steps to steer it away from the limits or develop policies that are effective at the limits. Chaos or wide oscillation can be avoided by slowing the system down, reducing feedback in the system or decoupling elements in the system. Alternatively, a system suffering decline due to excessive stability can be pushed toward chaos.

3.6. Chapter Summary

The complexity of public sector problems call for computer based DSS and this complexity makes the application of OR techniques dependent on the electronic DSS. A Decision support system is a computer information system which provides information as a basis for non-routine and semi-structured decision-making. Operations research is aided by a diverse collection of computer-based methods and tools for building and solving models, which we refer to as *decision technology*. The confluence of OR and decision technology allows managers to better convert data into information and provide powerful insights for decision-making. DSS is intended to provide managers only with a focused support for one or more activities within the decision processes and not replace them. Because of this limitation, we must become aware of the nature of available support a DSS can offer. Then we can see the need to incorporate DSS technology in those problem contexts where it is appropriate. Usually a computerized DSS may be needed for speedy computations, increased productivity, technical support, qualitative support, competitive edge, and overcoming cognitive limits in processing and storage. In addition, group decision-making is supported by support systems to overcome weaknesses inherent in traditional meetings.

Decision support systems must have the attributes of an MIS as well as the decision-making or decision-aiding capability of OR models. DSS are extremely user-friendly, requiring only a little knowledge of computer use, and they are flexible enough to support the different decision-making styles of a variety of users. While they may obtain data from a management information system, other data are supplied by the user in an interactive mode. It is this incorporation of the human judgment process that further distinguishes DSS from other information systems. From the list of software mentioned in this chapter, the application of spreadsheet add-ins (Premium Solver, and What's*B*est), and V.I.S A. are demonstrated in the next chapter, in the Ministries of Health and Fisheries.

Developing countries face opportunity costs if they delay greater access to and use of information infrastructure and information technology, which together make up information and communication technologies (ICT). In the face of fast diminishing resources, information technology can be used very effectively as development instrument to increase the effectiveness and efficiency of development programs of developing countries.

The Internet is at the core of a change in getting access to information in a timely manner and is influencing the way governments govern and communicate with their people. Internet groupware was used to support a public discussion which shows the potential of the Internet to integrate public knowledge into decision-making process. Mobile phones are also in the chain of the decision-making processes. People will value information on mobile phones that leads to better decision-making—saving them time, money or hassle. A new level of mobile interactivity is decision support—offering mobile information that helps people make better decisions while on the move.

Similarly, Geographic Information Systems (GIS) have become significant decision-making tools in the public sector as their capabilities have been enhanced. By inputting the data into a GIS one will have knowledge of spatial properties and spatial relationships which were not explicitly known before. Maps are often used to bring into public view the results of alternatives People can access and view alternative sites for new facilities before decisions are taken. Through broader access to GIS data it is expected that people can analyze and deliberate the pros and cons of values, goals, objectives, and criteria describing public and public-private problems at various scales.

As a challenge to OR and DSS the characteristics of complexity give rise to the unfortunate situation where the ease with which symbols can be made to represent something vanishes. Chaos theory suggests that many of our assumptions about the predictability of events are misplaced. A chaotic situation is characterized by the absence of regularities which prevents the accurate prediction of what will happen next. An important concept underpinning chaos theory is that of non-linearity. Many of the formal techniques of decision-making rest on assumptions of linearity. Chaos theory would seem to make decision-making more difficult since it suggests that small changes can have major and unpredictable consequences for the system overall. The existence of the Butterfly Effect indicates a tendency to disorder rather than order. Nevertheless, we are not without hope amidst the complex phenomena of nature as computer technology has opened up new possibilities for the modeling of complex systems. Moreover, complexity can be handled by crisis management, experimentation, and exploiting stability-instability boundaries.

Despite their wide-spread demand and applicability there are some impediments to DSS which include lack of user demand, lack of system designer motivation and expertise, reluctance to change, and increased risk of failure.

Chapter IV

Application of Decision Support Systems in the Eritrean Public Sector

4.1. Introduction

The chapter opens by introducing Eritrea with its people, historical and economic conditions. In the subsequent sections the status of OR and DSS in the Eritrean public sector is surveyed briefly. The researcher has visited the Ministry of Land, Water and Environment; the Ministry of Education; the Ministry of Health; the Ministry of Agriculture; the Ministry of Fisheries; the Commercial Bank of Eritrea; and the Grain board in Eritrea and gathered relevant data. These organizations were selected as candidates of study because there is wide and immediate applicability of OR/DSS techniques. However, this should not be taken to mean that the role of OR/DSS is diminished in other sectors.

Although unpublished papers from the organizations were used as sources, the researcher's main method of data collection were interviews with Department heads and personal observation. The main focus of the author has been on the Ministry of Land, Water, and Environment and specifically on the Department of Land, where the distribution of land for housing is underway. The rest of the organizations are discussed briefly to have an overview regarding the applications of OR and DSS.

Primarily, in the Department of Land, the model applied for distribution of land for housing is assessed. Specially, the problems with the quota method, weights and scores; lack of multidisciplinarity, exhaustiveness, authenticity, transparency; time lag, and the decision support applied will be discussed. As a remedy to the identified setback, a model that functions in a software is proposed to overcome the shortcomings of the model employed by the Department of Land.

Secondly, in the Ministries of Health and Education the level of MIS, forecasting, inventory, facility locations, and DSS are briefly evaluated. Thirdly, project management in the Ministry of Agriculture is discussed. Fourthly, in the Ministry of Fisheries the author attempts to find out their method of ensuring sustainable fishing practices. Then, the applicability of a typical multiple objective problems will be demonstrated in Excel Add-in programs. Fifthly, the status of the DSS in the Commercial Bank of Eritrea will be touched on. Finally, the decision of the Grain Board of Eritrea to locate stores in Dekemhare will receive some attention.

4.2. Overview of Eritrea

Eritrea is currently one of the youngest independent states. According to Maxon (2004), and Columbia Encyclopedia (2004), Eritrea, independent state in Africa, is bordered on the east by the Red Sea, on the southeast by Djibouti, on the south by Ethiopia, and on the northwest by Sudan. Formerly under Italian and British control, Eritrea was taken over by Ethiopia in 1952, provoking a long war of liberation that began in 1961 and culminated in Eritrean independence in 1991. Following liberation the Eritrean People's Liberation Front (EPLF) took over control of administration but agreed to hold a referendum which was totally approved by the electorate in 1993.

Eritrea covers an area of 124,320 sq km and its Red Sea coast stretches for more than 1,000 km. The estimated population of 3.5-4 million is diverse, reflecting many languages, cultures, and religions. The literacy rate is about 20%. Approximately half of the population are Christians and the rest are Muslims.

The nation possesses potentially valuable potash deposits and possibly gold, iron, petroleum, and salt; but exploration and exploitation of its mineral resources were severely hampered by three decades of war. Eritrea's economy suffered massive damage and dislocation as a result of drought and the famine during its 30-year-long independence war with Ethiopia and hurt again by the strain of the 1998-2000 border war with Ethiopia. At the time of independence the country's industrial base was shattered.

The economy is largely based on subsistence agriculture, with 80% of the population involved in farming and herding. Eritrea faces daunting economic problems. Recovering from war, resettling of people, attaining food self-sufficiency, and rebuilding transportation infrastructure, all demand careful planning and allocation of scarce resources as well as international assistance. Many Eritreans work outside the country, and their remittances substantially augment the GDP. Imports (consumer goods, machinery, and petroleum products) greatly exceed the value of exports (livestock, sorghum, and textiles).

Eritrea was the last country in Africa to get local access to the Internet. It officially launched its Internet service in March 2000. It has few ISPs (Internet service providers) although POPs (points of presence— physical locations that are access points to the Internet) are now being established in larger towns. The internet service in Eritrea is very slow. The BBC (2000) indicated that there are still considerable technical problems and the Gateway bandwidth of 512 kilobits per second is shared by the four ISPs, which reduces the speed of browsing for users. According to WebTIMES (2003), while some broadband users in developed countries have as much bandwidth for their personal use (notably in South Korea), some entire countries in Africa including Burundi, Eritrea, Niger, Central African Republic, Chad and Equatorial Guinea, have less bandwidth than this personal use. However, the Telecommunication Services of Eritrea indicate that currently the Eritrean bandwidth has been upgraded to two megabytes.

Though by now there might have been considerable increases, computer resources were scarce up to 1999. According to the Eritrean Technical Exchange (1999)—a US NGO— there were few computers (perhaps 10,000 to 30,000 in the country—less than one for every 100 people.

Given its successive colonial history the Eritrean public administration has been characterized by discontinuities. After every exchange of hands all colonial masters dismantled their predecessor's administrative system, resulting in a low institutional base. Accordingly the civil service was structured only to fulfill the colonialists exploitative and repressive objectives; good governance and efficient service delivery were not in the agenda. Hence, the public service in Eritrea is young, only as old as its liberation, and it is still in the process of laying the institutional foundations.

After liberation the new government had to fill the administrative vacuum mostly with its ex-fighters who were not experienced and trained in public administration and support technologies. Among other things, constraints such as financial, know-how, and lack of awareness may hamper the development and acceptance of decision support technologies.

This situation poses challenges to the public management in Eritrea and will do so for some time to come.

4.3. The Ministry of Land, Water, and Environment

4.3.1. The Department of Land

The Department of Land in Eritrea is one of the departments of the Ministry of Land, Water, and Environment. Its responsibility includes land-use planning, cartography, and land distribution based on the Land Proclamation. In Eritrea, even though there is land proclamation, there is no land-use policy. The absence of this leads to inappropriate use of land. Without a land-use policy it is very difficult to identify which type of land is to be allocated for which purpose. To enable decision makers to make appropriate decisions, land has to be categorized according to its potential use. Based on soil depth, surface stoniness, slope, and exposure to soil erosion all land has to be classified so that it can be allocated easier either for housing, agriculture, grazing or other purposes.

Application of OR/DSS without such a policy framework may be ineffective and futile. The absence of such a policy can lead to inappropriate use of land and wastage. Given its climate, topography, and infrastructure, land for housing in Eritrea is one of the most crucial issues requiring careful and informed decision-making approaches.

Historically, in Eritrea a great portion of land is owned by the villages communally. Wherever there is a need for the expansion of towns, land has to be taken from the villages without compensation, as it is proclaimed to be government's property. However, this is not done without complaints from the villages, which aggravates the shortage and widens the gap between supply and demand.

According to the Land Proclamation of Eritrea, all land belongs to the government and cannot be sold, and in principle every Eritrean is entitled to get a piece of land for housing for free anywhere according to his/her choice. By the same token, investors are also supposed to get land on demand, provided that their investment proposal is approved. Based on the proclamation the government has the right to distribute land to those who demand it for housing or investment wherever it is available. Land availability is dependent on the location because the population distribution is not equal in the country, making it scarcer in the highlands where there is overcrowding.

During 2001 the Department of Land distributed forms to be completed by applicants demanding land for housing in the town of Dekemhare—40 km south of the capital city. The demand was very high compared to the land made available for distribution as approximately 9700 people applied for housing. However, the land available (planned to be distributed) was enough for 1730 houses. That is, about six people were competing for one house. Thus, the Department was faced with the crucial issue of how to distribute this scarce resource when there was a wide gap between supply and demand. It is not an easy task to allocate by mathematical formula when the issue of equity has also to be considered.

To ensure equity among the applicants, the Department categorized them into seven social groups according to their social status as identified below:

a) Ex-fighters (demobilized and not demobilized);
b) Militia/Reserve army;
c) National service;
d) Civilians (men) over 40 years of age, living within the country ;
e) Eritreans in Diaspora over 18 years of age, that pay 2% of their income to the government of Eritrea, as a national duty;
f) Women residing within the country, who have children and are exempted from national service; and
g) People under 40 years of age and exempted from National Service.

The Department then assigned a quota of land to each social group after which it prioritized (within a social group) according to the weights given with the help of Microsoft Access. After processing, the output of the model was announced. However, there were complaints by those who were not eligible to receive land, according to the criteria set by the Department. The applicants who observed some people to get land, especially whom they perceived as lower in status in comparison with themselves, could not tolerate the announcement of the results. Some of the complaints were objective and soon the weakness of the model became apparent. This led to the revision of the model and the Department reprocessed the applications, resulting in a minor change in the output. Some who were eligible in the previous process became ineligible in the revised process and vice versa. This phenomenon negatively affected the credibility of the model employed.

The categorization, and the weights given to the criteria in the prioritizing model are shown in the Table IV-1.

4.3.1.1. Weights Given to the Criteria

Social Group	Criteria	Rank	Weight out of 100
Ex-fighters (demobilized and not-demobilized)	Date of enrolment in the army	1st	35
	Position	2nd	30
	Age	3rd	15
	No. of children	4th	12
	Marital status	5th	8
Militia/reserve army	No. of children	1st	35
	Age	2nd	30
	National duty	3rd	20
	Marital status	4th	15
National service	No. of children	1st	40
	Marital status	2nd	35
	Age	3rd	25
Civilians over 40 years of age living within the country (male)	No. of children	1st	50
	Age	2nd	30
	Marital status	3rd	20
Eritreans in Diaspora over 18 years of age that pay 2% of their income	Age	1st	40
	National duty	2nd	30
	Marital status	3rd	15
	No. of children	4th	15
Women residing within the country who have children and are exempted from National service	No. of children	1st	50
	Age	2nd	30
	Marital status	3rd	20
People under 40 years of age and exempted from National service	They work for the government with special skills or are disabled. Since they are few—they may be weighed with their social group or receive special treatment.		

Table IV-1. Weights given to the criteria of social groups.

Source: Department of Land (2003) Translated from Tigrinya by the author.

4.3.1.2. Analysis of the Criteria and Weights

a) Ex-fighters

The Department of Land applied the subcriteria: *date of enrolment, position, age, number of children, and marital status* to the ex-fighters and ranked them according to certain weights attached to them (see Table IV-1). It then scored each subcriteria according to the duration (grouped into seven categories) each ex-fighter served in the liberation struggle. The problems with this classification can be summarized as follows:

i) *Date of enrolment:* it was scored by grouping the years, that is a score was given to a range of years (e.g. 1971-1973; 1974-1975). The range was not equally spaced and the corresponding scores given varied disproportionately (from 2% to 3%).
ii) *Position:* it received a significant weight and was scored by dividing it into ten categories. The scores given did not vary proportionally from category to category. Moreover, the categorization did not show for how long an incumbent has been in that position. In this case, there was a danger of treating people unfairly by equally scoring people currently in position, say, for one year and people who had been in the same position for ten years.

In the case of ex-fighters, position should be looked at from the perspective of before and after 1991 (year of the independence) because this could enable to weigh the demobilized and not demobilized ex-fighters in the same scale, as they claim to have the same rights in terms of privileges. The current positions of the ex-fighters who are not demobilized, and the previous positions of the ex-fighters who were demobilized after independence, do not reflect the true relative worth of the individuals when compared to one another. For example, one ex-fighter demobilized from the post of battalion commander is registered to be a battalion commander for ever, while another, who at that time was a platoon leader (lower than the former) now he may be a brigade commander (higher than the former). Even though current position had to have weight it should have been treated separately in order to give the demobilized ex-fighters equal footing. If you try to compare them (demobilized and demobilized) in terms of position irrespective of time (when?) the demobilized ones will be less disadvantaged, if they are to be weighed in the same scale.

iii) *Number of children*: the Department did not distinguish between minors and majors. Children have to be classified into minors and majors, because the majors are expected or have to be independent sooner or later, while the minors will be dependent for a longer time.

iv) *Marital status*: an unmarried ex-fighter has been given a zero score while an unmarried militia is given a score of ten. This is questionable; there should be uniformity of weights across the criteria.

b) The other social groups

The above arguments can be applied to the rest of the social groups in the case of age, number of children, and marital status. However, despite the fact that position is an important ingredient for all the social groups, it is taken as a criterion only in the ex-fighters' category. To have a balanced approach, position should be applied across all the identified social groups.

In the subcriterion *national duty,* a score of 20%, 20%, and 30% is given to militia/reserve army, national service, and to those living in Diaspora who pay 2% of their income respectively. Assigning a higher score for those paying 2% of their income and are living in Diaspora, rather than for being militia/reserve army or doing national service creates the potential for complaints. Serving as militia/reserve army or doing national service involves staking one's life fighting the enemy (valued higher at least by those involved). But assigning a higher score to them may raise questions by those adversely affected by the decision. To counter this possibility of complaints, the author proposes that *national duty* as such has to be given a specific weight that cuts across all the social groups. It should be assigned on merit and should not differ n different groups.

4.3.1.3. Problems in the Model

The basic problem not related to the model has been a big mismatch between demand and supply. In this situation, in which only about one out of six applicants are supposed to get land, dissatisfaction is expected to be high. It goes without saying that those who will be dissatisfied will be much more in number than those who will be satisfied. However, to mitigate (at least to make less severe) the dissatisfaction, the method followed and the model used should have been transparent, comprehensive and inclusive (participatory).

The main problems of the model can be summarized as follows:

a) The quota method

The quota was used for political reasons, that is, to ensure equity of access to housing. The applicants have been categorized, as mentioned above, into seven social groups. One of the arguments of the Department of Land was that if all social groups were to be weighed together in the same scale the output would be skewed to one social group.

However, the weakness of the quota method becomes clear if we consider the following example. According to the quota method, if two applicants were a father (who joined the liberation struggle in 1979) and a son (who is doing national service), there is a probability that the son can get land (competing only in his group) while his father cannot. This can happen because only those who were enrolled in the liberation struggle before 1978 were eligible to get land in this particular situation. It means that for ex-fighters to be eligible to get land, they must have served in the armed struggle for at least 14 years (1977-1991) before liberation. While the other groups can have the chance of getting land if they did their national duty for at least 18 months, the ex-fighters were required to serve for more years as indicated above. This intolerable situation alone can invalidate the quota method. Had they been weighed in the same scale the father-son scenario could have been averted. A model that rectifies the process is proposed in Figure IV-2.

The argument of the author is not that the ex-fighters should be the only beneficiaries. The point is, the model could have been designed in a way that would enable decision makers to be fair, reasonable and transparent in the distribution of land. To avoid this situation, instead of allocating land based on quota, all of the applicants should be seen as one group and compete on the same scale. The model should be seen as operating in one system and all applicants should be allocated weights in the same way.

b) Uniformity of weights and scores

It can be observed from procedures of the Department that some of the weights and scores are applied:

- Differently to different groups;
- To only some of the social groups; and
- To a range of elements of a criterion and subcriterion, e.g. the same score is given to age 46 and 48, as in the age range 45-49 years.

The application of different weights and scores to similar criteria for different social groups is not fair. For instance, a civilian 40 years of age having 4 children will score 50%, while an ex-fighter of the same age and having the same number of children will score only 12%, according to the model. The disparity of weights for the same criteria is shown in Figure IV-1.

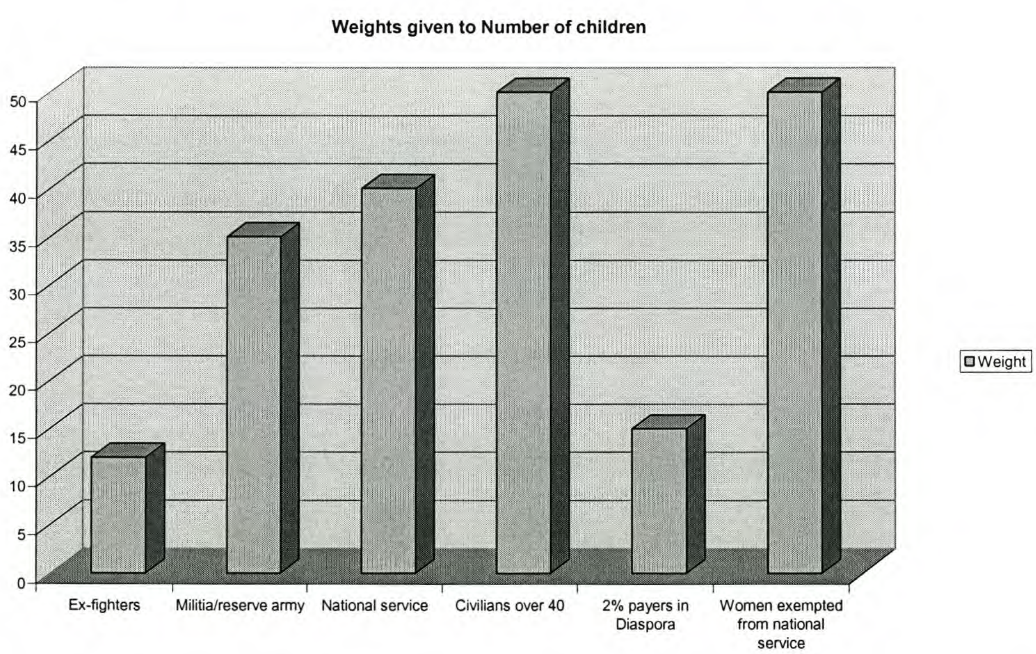


Figure IV-1. Comparison of weights of the same criterion (no. of children) across social groups.

Even though the number of children is taken as an example in Figure IV-1, this disparity of weights and scores is observed on almost all criteria across social groups which makes it very difficult to convince the public, because the effect of age, number of children, and marital status is similar in all groups. These social groups have to be treated equitably. Other things being equal, a family with five children will have the same housing need irrespective of social group. So a family of five children should score equally in all social groups regarding the criteria *number of children*.

The Department of Land has considered gender as a subcriterion only in Eritreans in Diaspora and ex-fighters, but not in the other social groups. However, there is no convincing reason why it should be applied only to certain groups and not to others. It has to be uniformly applied across all the social groups that are competing for the same resource.

The range used in scoring can also create imbalance when scoring in the aggregate weight. For example, according to the model of the Department two men, one 45 and the other 49 years of age, are scored equally in the age criterion. It means an advantage of being older by four years has no any effect in the range of 45-49, while being one year older between two ranges, say 45-49 and 39-44, that is if one is 44 and the other is 45 years of age leads to a 2% difference in the score. This, added to the effects of other criteria, may have substantial effect on the results.

Similarly, in the number of children criterion, a family having two children scores more than a family having one child, while a family having three children scores the same as a family with seven, ten or more children. In the current situation of Eritrea, where there is a big difference between demand and supply of housing the number of children has great influence on one's chance of renting a house. The more children one has, the less one is able to find a house to rent. Hence, the score must be proportional to the number of children. The model should be able to accommodate the variation and to take into account every child by giving a respective score.

Generally, giving appropriate weights to criteria before a decision is reached is likely to guard decision makers against bias and arbitrariness. Unless due weights are given there are dangers that decisions may lack uniformity and similar groups and individuals be treated differently and unfairly. Weights have to be transparent as well, in order to avoid manipulation for some political ends.

c) Multidisciplinarity

The model and the criteria were developed by the internal staff of the Department of Land only. However, if it is understood that the effect of the decision regarding land for housing cuts across (affects) all members of society, including future generations, it becomes self evident that the issue should naturally be addressed in a multidisciplinary manner. For this reason, it is imperative to have inputs from all walks of life—traditional and scientific. Various professionals from different disciplines including people rich in indigenous knowledge could play an important role in building the model. The selection of the criteria and assigning of weights and scores, clearly, transcend the boundaries of a single discipline.

Allowing participation by other sectors and the public not only helps develop a sense of ownership and understanding of the ultimate solution, but it is a right and can be the source of important information throughout the problem solving process. The land issue is a multiobjective one in which the Department has to consider economical, environmental, and social aspects of society. These aspects cannot be tackled by an expert alone and requires the involvement of all. No decision maker is multilateral enough to understand all input requirements and ramifications of this decision.

Moreover, there has not been adequate cross-sectoral collaboration even with the immediately relevant ministries. One of the major stakeholders of the housing issue is the Ministry of Defense because many, if not a majority, of the applicants (ex-fighters, members of national service, and militia/reserve army) are directly administered by it. Hence, the Ministry of Defense should have been consulted and should play a significant role in the decision-making process.

d) Exhaustiveness

Unless the required data is captured in detail, the decision may not be reliable and it will be very difficult to handle the ensuing complaints. The data gathered, though necessary, is not sufficient for informed decision-making. In addition to data concerning ex-fighters, the data that is missing in the Department's model include position, duration of national duty[1], and war injury.

Similarly, *need*, which is overlooked in the Department's model, is an important factor in housing decision-making. Broadly speaking, as there is a huge housing backlog in the country, the applicants have similar housing requirements, but in various degrees of need. Some applicants may not be in urgent need, while others are in desperate need. Some applicants live in government rented houses, some have rented privately owned (less secure) houses, some live in their parents' houses and still others own houses as *tisha*[2]— where some applicants have *tisha* in Dekemhare. There is a village called Dekemhare as well, and some of its land is merged with the town Dekemhare. Based on the above and other arguments the model should incorporate need analysis and accordingly give highest priority to those applicants who are considered in greatest need.

According to Pinkus and Dixson (1981:51), a housing points scheme has to be:

i) *Consistent*—sufficient agreement has to be reached beforehand between all the officials concerned on the measurement of housing need, so that once it was devised the scheme can confidently be applied to all applicants and obtain the required results.
ii) *Comprehensive*—the scheme has to apply to all housing applicants.
iii) *Comprehensible*—the means of assessing relative housing needs should be clearly understandable to applicants and to taxpayers, and should offer the minimum opportunity for providing misleading information to the department.

e) Authenticity

The Department has been very strict in authenticating the date of enrolment of the ex-fighters and this had to be supported by an official document. However, it was not only the date of enrolment that is involved in the decision-making. As indicated above, the criteria are many and all of them should have been officially confirmed by relevant

[1] Though it is for 18 months, currently the duration is not limited because of the recent war.
[2] A right of access to land because the person was in a specific village.

authorities. For instance, despite a heavy weight given, applicants were not required to present official confirmation of the number of children they have, and it was possible for some people to exaggerate the number of offspring in order to maximize their chances.

f) Time lag

The data (application) was collected in 2001. The passage of time between the collection of data and the making of the decision can invalidate the data, and this can have a significantly adverse effect on the decision. The decision for the distribution of land in Dekemhare was announced in 2003. Since social elements are dynamic many of the collected data had possibly changed in the meantime. Among other things, the number of children increases or decreases, and marital status varies. Hence, decisions should be made as soon as data is gathered before they become outdated. According to Giannatasio (1999:152), when changes occur over a period of time in the group being studied, there is threat to validity.

g) Transparency

Transparency is practiced not only because tax payers have a right to information but also because it can minimize dissatisfaction. Before reaching a decision, the criteria and weights employed should be enriched by public discussion and feedback. This ensures that all variables necessary to make a decision are taken into account. This will enhance the quality of decision-making. If everyone affected can openly evaluate the results against the publicly agreed and comprehensive criteria, there will be no cause for complaint.

h) Decision support

For the Dekemhare housing issue Microsoft Access (a database software) has been employed as a decision support tool. However, for such a complex issue that involves many criteria and subcritera, and where a need for efficient sensitivity analysis arises only a specialized software like V.I.S.A. (Visual Interactive Sensitivity Analysis) should be employed for a better solution. V.I.S.A is decision support software that can handle an infinite number of options (SIMUL8 Corporation, 2003). It can perform sensitivity analysis that can be done more efficiently and instantly and more alternatives can be observed before any decision is reached. The 'what if' scenarios can help to change the weights and scores assigned to each criterion and possibly improve the model itself before results are announced . Of course, the Department can also judge intuitively who should be eligible to get land, and the model can be developed to suit this intuition with the help of sensitivity analysis.

4.3.1.4. A Proposed Model

Based on the above discussion the author proposes the model shown in Figure IV-2 which is implemented in V.I.S.A. The author has attempted to incorporate all the criteria and subcriteria in their proper perspective in this model. This model can be applied not only in Dekemhare but also in similar situations where there is a need for decision concerning land distribution for housing, or other demand for prioritizing. It uniformly applies weights and scores to similar criteria and puts all applicants in the same scale (system) in contrast to the model applied by the Department of Land which assigns different weights to the same criteria. The proposed model attempts to be exhaustive by including all relevant factors. Moreover, this model enables the manipulation of the weights to give many alternative solutions in a short time. Building such a model is the critical component in the decision-making process, and should be validated before it is used. Care must be taken not to be manipulated by decision makers to provide a predetermined outcome for political ends. As mentioned above, the model has to be built by a multidisciplinary group and enriched/refined by the public. This model, suggested by the author, is only tentative that can serve as a starting point for discussion. Its objective is to sensitize to the need of a comprehensive model and relevant software.

Actual data concerning the applicants could not be applied in the model because the data required by the proposed model had not been collected by the department. Hence, hypothetical data has been taken to demonstrate the applicability of the model.

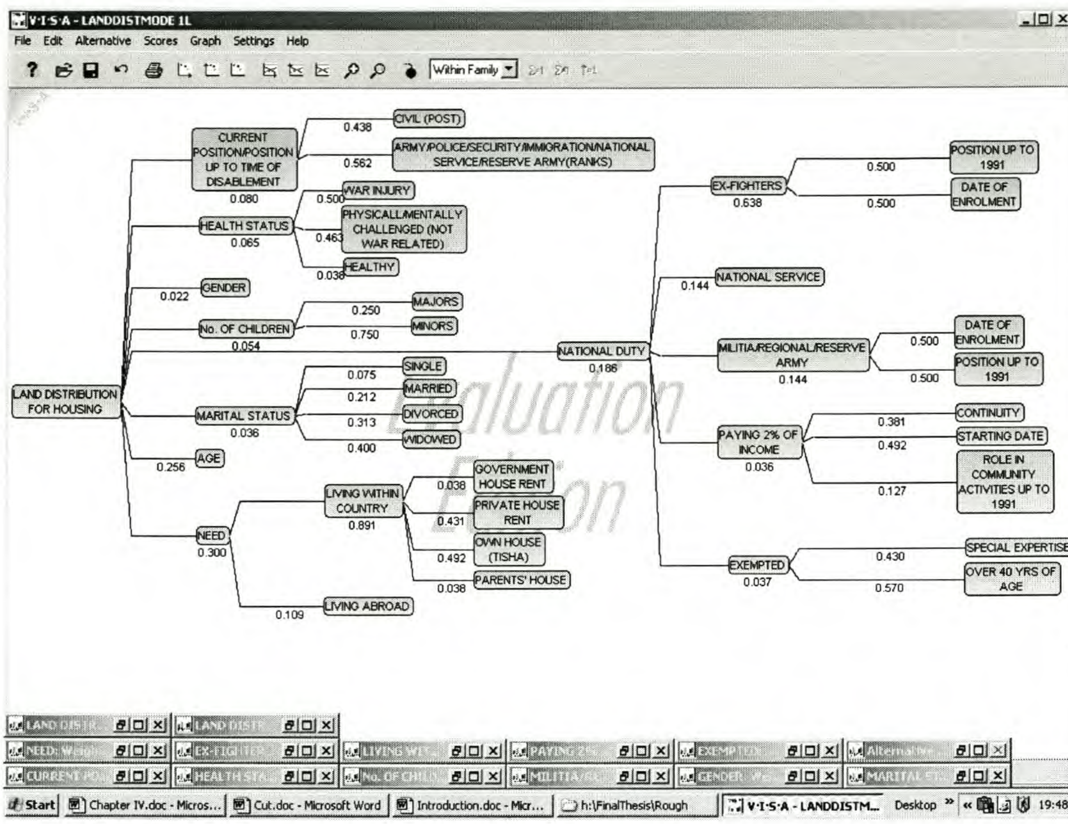


Figure IV-2. A proposed model for prioritization.

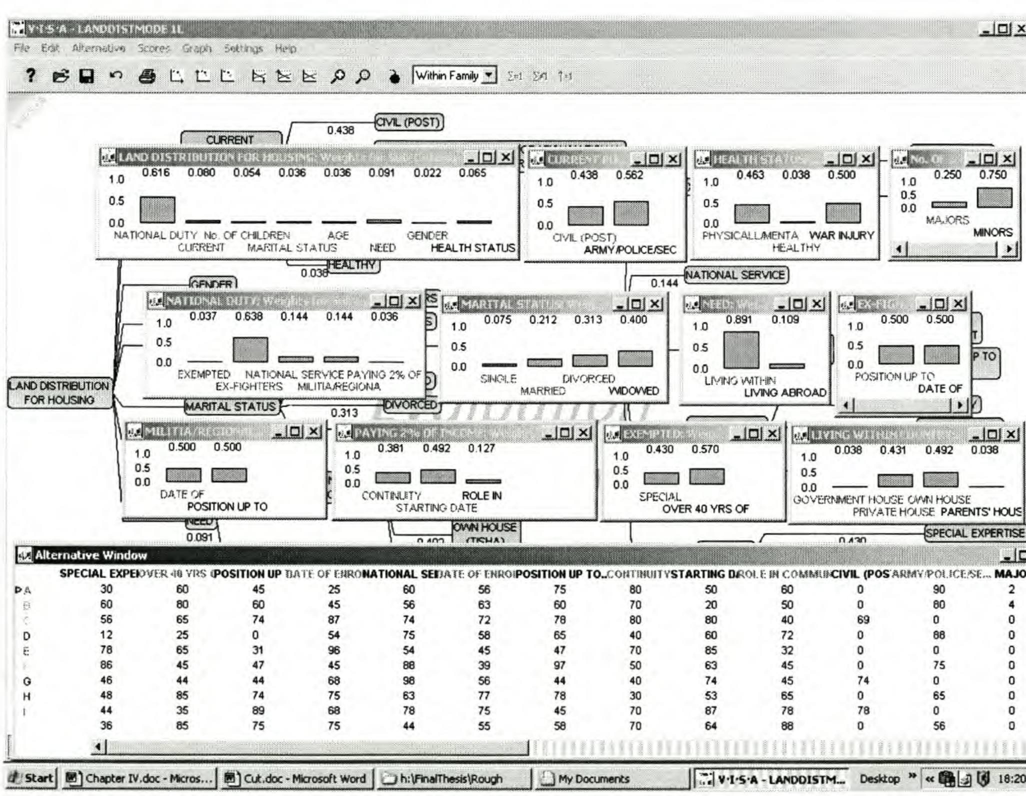


Figure IV-3. A model showing weights and scores for the distribution of land for housing.

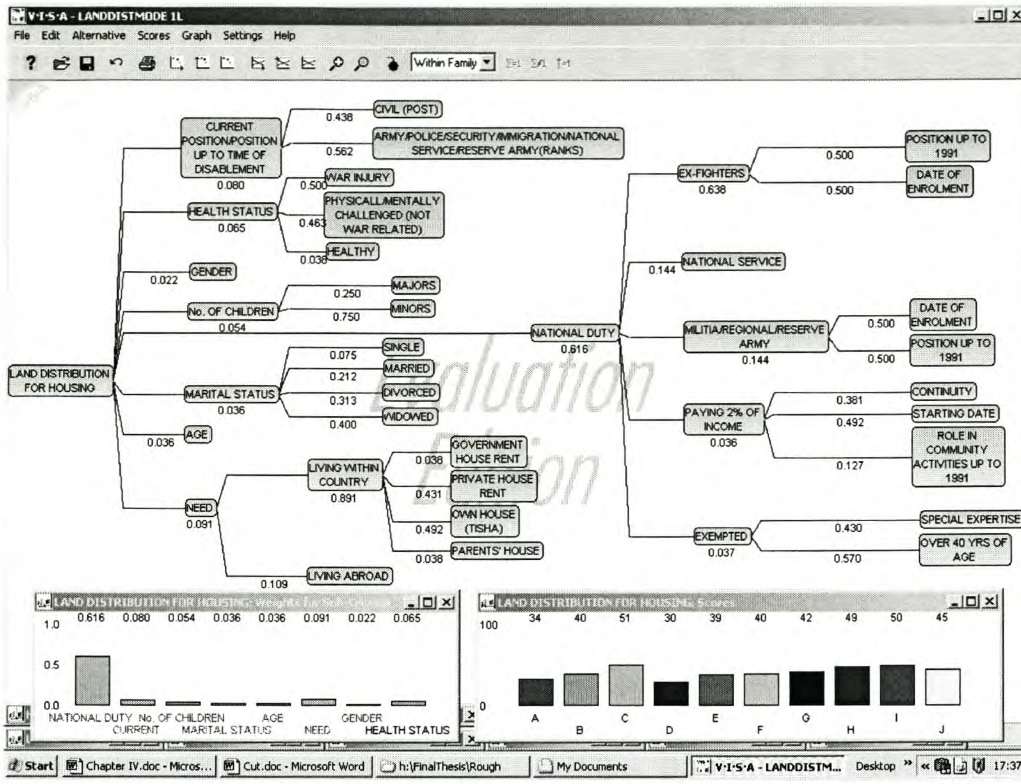


Figure IV-4. Output of the model when *national duty* is given highest weight.

As it is seen in Figure IV-3, the criteria and subcriteria for land distribution for housing are given weights (shown in bar graphs in the small windows) and scores (shown in the alternative window) according to their relative importance. A preliminary output is shown in Figure IV-4, where when *national duty* is given highest weight (left window), applicant *C* scores the highest (right window) and gets priority to obtain land. The hierarchy goes on as shown in Figure IV-4. If the results do not appeal to intuition, the weights and scores originally given can be varied until the decision-makers are convinced of the validity of the model.

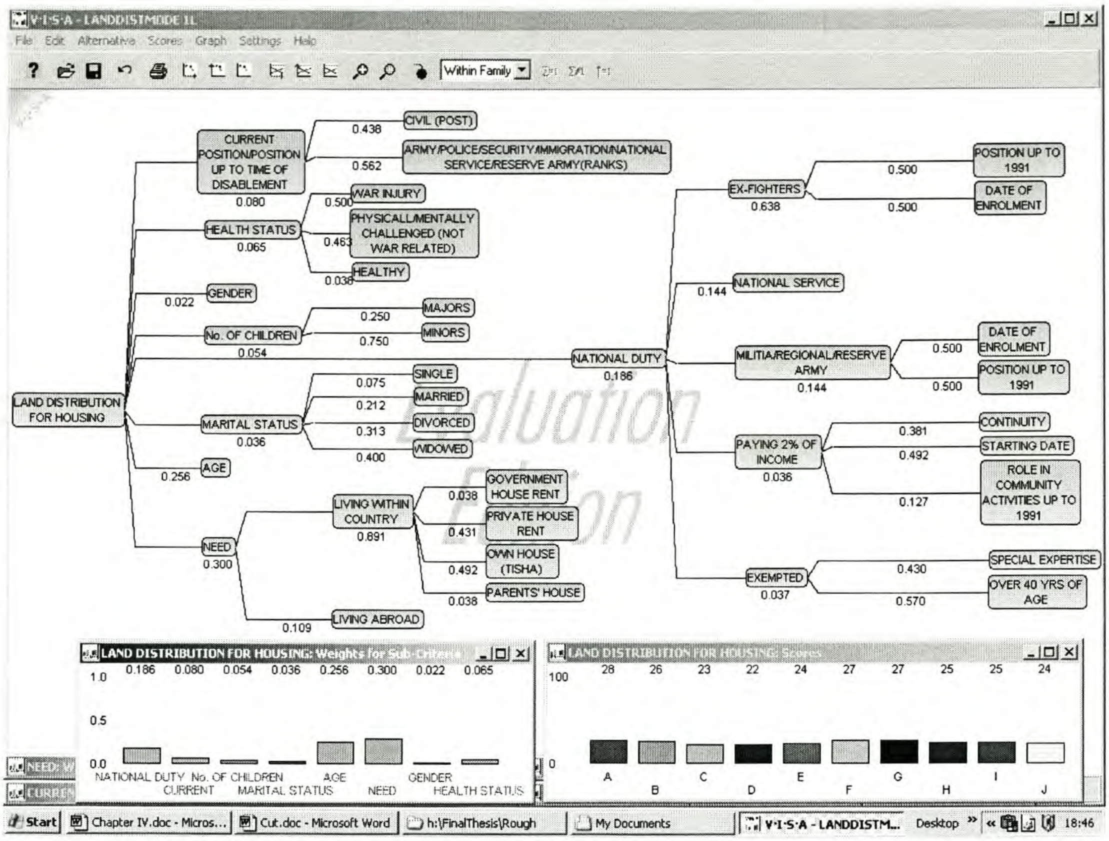


Figure IV-5. Output of the model when *need* and *age* are given a higher weight than *national duty*.

Ease of sensitivity analysis is one of the attributes of the model. As shown in Figure IV-5 we can get different outputs by varying the weights. This figure indicates that when *need* and *age* are given more weight than *national duty*, individual *A* scores the highest and is given priority to obtain land.

The scoring can be operationalized by taking into account every detail of the criterion (see Table IV-2). For example date of enrolment is operationalized by giving a score (value) to every year of service not to a group (range) of years, as has been done by the Department of Land; and a family which has seven children scores higher than a family with six children as opposed to giving the same score as in the Department's model.

Table IV-2. Operationalization of subcriteria.

Sub criteria	Elements of operationalization	Score
Post	*Unit head, division head, department head...*	Each to be given proportional numerical value
Rank	*Corporal, sergeant, sub lieutenant...*	"
Gender	*Male, female*	"
Majors	*Number of children*	"
Minors	*Number of children*	"
Position up to 1991	*Unit leader, platoon leader, company leader ...*	"
Date of enrolment	*1961, 1962, ...1991*	"
War injury	*Level (stage) of injury*	"
Round	*1st, 2nd, 3rd...*	"
Continuity	*Bad, good, very good...*	"
Starting date	*1991, 1992, 1993...*	"
Role in community activities up to 1991	*Bad, good, very good...*	"
Special expertise	*Low, medium, high...*	"
Over 40 years of age	*41, 42, 43...*	"
Physically/mentally challenged	*Level (stage)*	"
Single		"
Married	*Duration (years)*	"
Divorced	*Duration (years)*	"
Widowed	*Duration (years)*	"
Age	*18, 19, 20...*	"
Government house rent	*Amount paid*	"
Private house rent	*Amount paid*	"
Own house	*Space*	"
Parent's house	*Space (allowed for him/her)*	"

In addition, Figure IV-3 shows that a sample[3] of ten applicants (named A, B,...J) has been taken and prioritized by the model in which the total score of every applicant is indicated graphically as well as numerically. All applicants can be listed that way. The model gives

[3] This is not real data, but hypothetical data, because, the data available in the Department is not detailed enough for the new model.

the opportunity for sensitivity analysis by which decision-makers can vary the weights and scores until they feel the model is valid.

4.3.1.5. Other Decision Support Systems Used

The Department of Land has a relatively well developed division of cartography. The special software applied in this division are: AutoCAD, ArcIinfo, GPS Pathfinder Office, and ArcView GIS.

a) AutoCAD

AutoCAD is a general purpose computer aided drafting application program designed for use on single-user, desktop personal computers and graphic workstations. AutoCAD is an interactive drawing system designed to permit a user to construct or edit a drawing on a graphics display screen (University of New South Wales, 1999).

b) ArcInfo

Within the ArcGIS software family, ArcInfo is the most comprehensive GIS available. It includes all the functionality of ArcView and ArcEditor and adds the advanced geoprocessing and data conversion capabilities that make ArcInfo the de facto standard for GIS (ESRI, 2004).

c) GPS Pathfinder Office

It adds value to GIS data collection and data maintenance projects. It supports all aspects of GIS data collection and data. With GPS Pathfinder Office, files can be imported from a number of GIS and database formats so GIS data can be taken back to the field for verification and update (Trimble Navigation, 2004).

d) ArcView GIS.

ArcView GIS software is used for desktop Geographic Information Systems analysis and map presentation. With ArcView, you can create dynamic maps using data from virtually any data source including the Internet. Computer generated maps are used as a platform for geographical analysis (University of Wisconsin, 1998).

The division of cartography uses these software for the preparation of maps. One of its products as seen in Annexure D, is a map of land allocation plan of a village called Adi-Ke.

4.3.2. The Department of Environment

Among other effects, greenhouse gas concentrations in the atmosphere are creating imbalances in the natural cycle of the earth's climate. For sustainable development, human activities have to be controlled to maintain a certain level of pollutants that is not hazardous and is compatible with development. Operations research can help in the preparation of models to calculate the inventory and optimal level of pollutants in the environment.

According to the Department of Environment (2001:3), which is under the Ministry of Land, Water, and Environment, Eritrea's inventory of greenhouse gases was conducted using the revised 1996 International Panel on Climate Change (IPCC). The inventory of greenhouse emissions by sources and the removal by sinks was carried out, taking 1994 as the base year for carbon dioxide, methane, nitrous oxide, carbon monoxide, nitrogen oxides, and non-methane volatile compounds. The inventory addressed six sectors, namely, transport, industry, agriculture, land-use change and forestry and municipal solid waste.

The limitations of greenhouse gas inventory, as the Department of Environment (c2201:5) identifies, are the lack of country specific emission factors and emission ratios which are critical for undertaking a national greenhouse inventory. The lack of time series data has also been identified as another obstacle.

The Department of Environment has software called Greenhouse Gas Inventory Software which enables users to calculate pollutants. However, it does not have a national standard that specifies the optimal level of pollutants allowed to be emitted or disposed of, that is commensurate with sustainable development. Major economic actors must not be allowed to pollute the environment in an uncontrolled way and must know the maximum limit for their emission or use of chemicals that have a waste by-product. For example, the leather factory in Asmara uses chrome as a chemical ingredient without any limit, and its level of pollution and the disposal system must be checked. In general, the Department has to develop a model for national standards by which the government can decide on matters, including, the number and type of cars to be imported, the type of fuel to be used (e.g. leaded or unleaded), types and quantities of fertilizers to be applied, and methods of waste removal from households and factories. Currently these national standards are not in place.

4.4. The Ministries of Health and Education

The Ministry of Health and the Ministry of Education are some of the sectors which can benefit much from OR/DSS applications such as information systems, forecasting of employee requirement, population size projections, deciding the optimal number of service stations, optimal facility locations, GIS and automated billing systems.

a) Management information systems

Management information systems have the potential, including to improve decision-making responsiveness, quality of patient care, and productivity. They reduce waiting time for physicians' orders to become available, improve appropriate data availability for decisions about staffing pattern, scheduling, use of equipment and materials.

The information systems are in their infant stage in both ministries resulting in duplication of work and loss of financial and time resources. Patients often lose their cards and are registered more than once, because there is no patient identification number. This situation creates a problem when someone tries to follow up a patient's case. Staff waste time filling in forms instead of focusing on service. The system of billing is still manual and slow.

On the positive side, in the Ministry of Health there is a network that connects *Zoba* (regional) and national health offices. Data can be updated online on a weekly and monthly basis and paper work between *Zobas* (regions) and the head office is decreasing. The Ministry of Education has an educational management information system (EMIS) which is a local area network (LAN) and has connection via modem with *Zobas*.

b) Forecasting

What is the population size that will need primary health care and schooling during the coming years? How many service providers including doctors, nurses, laboratory technicians, and teachers should be produced every year, taking into account the attrition rate? How do we obtain a stable work force to meet the demands of the people for smooth and efficient service delivery given the unstable war environment? How many children will be enrolled in the coming years? To address these and other similar questions the ministries need scientific forecasting models. So far these predictions are not systematically made and most of the time the counting faces disparity between supply and demand.

The Ministry of Health only developed its first human resource plan in 2001 and has projections up to 2010. However, this is still on paper. The Ministry of Education uses the cohort-component method to project the population and number of school age children up to the year 2017. This cohort method takes into account different components of population growth (fertility, mortality, and migration). However, there are no projections regarding its human resources. To predict staff requirement by way of population growth is not efficient, because the employee situation has its own dynamism. The ministry has to develop models which enable staff needs for the coming years— to be predicted based on the factors that interact in the staffing pattern.

c) Facility locations

In the two ministries there are no documented sets of decision criteria for facility locations. Of course when confronted with such demands, say opening a new school or health facility, they take into account such matters as population size, distance from other villages, geographical situation, political and security reasons, health problems and others. However, what each of these criteria weighs against the others is not known. The ministries must have a well defined and documented set of criteria with relative weights for every decision situation they may face.

In the Ministry of Health, to a very limited extent, they try to assign weights and calculate manually in situations when they have to select among alternatives. This manual calculation, apart from not being reliable, limits the number of subcriteria and options that must be taken into account. Decision support system such as V.I.S.A. would properly and precisely handle the choice among alternatives, incorporating human judgment of course.

One of the decision problems required by the Ministry of Health is the location of an optimum ambulance center in Asmara. Currently the ambulance centers are in the hospitals which are not equidistant from all the farthest sections of the town resulting in unequal service opportunity to the citizens. Those who are farther from the station experience longer or delayed response time. To use the ambulances efficiently, it would be better to pool and locate them optimally. The proposed location, as indicated in Figure IV-6, for ambulance center is an optimal location calculated by the distance formula.

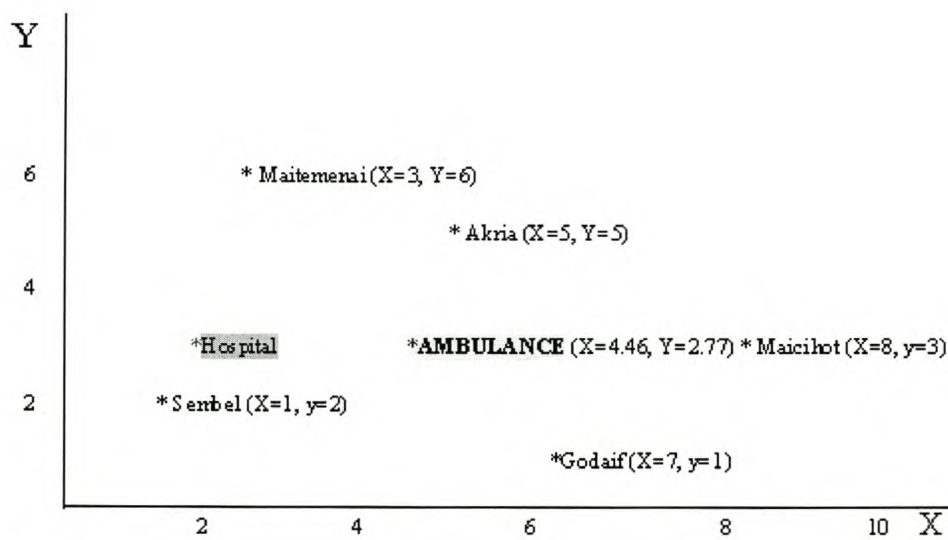


Figure IV-6. Sections of Asmara located in terms of X-Y coordinates, and optimal ambulance location.

In, Figure IV-6, the sections of Asmara are indicated in terms of approximate X-Y coordinates. The coordinates can be taken as equivalent to kilometers. For a speedy service, it is assumed that the distance of the proposed ambulance center should not be more than six kilometers away from the farthest point of the city so that the response time can be less than six minutes from the time of call. The distance of each location from the proposed ambulance station is calculated by the distance formula (applying

Pythagorean Theorem). The objective is to minimize total distance traveled by the ambulances as shown below.

Min:

$$\sqrt{(3-x)^2+(6-y)^2}+\sqrt{(5-x)^2+(5-Y)^2}+\sqrt{(8-x)^2+(3-y)^2}+\sqrt{(7-x)^2+(1-y)^2}$$
$$+\sqrt{(1-x)^2+(2-y)^2}$$

Subject to:

$\sqrt{(3-x)^2+(6-y)^2}\ \leq 6$ (Maitemenai distance constraint)

$\sqrt{(5-x)^2+(5-Y)^2}\ \leq 6$ (Akria distance constraint)

$\sqrt{(8-x)^2+(3-y)^2}\ \leq 6$ (Maicihot distance constraint)

$\sqrt{(7-x)^2+(1-y)^2}\ \leq 6$ (Godaif distance constraint)

$\sqrt{(1-x)^2+(2-y)^2}\ \leq 6$ (Sembel distance constraint)

The objective and constraints for this problem are nonlinear and the model can be implemented in a spreadsheet as shown in Figure IV-7 (solved in Premium Solver Platform), and similarly in Figure IV-8 (solved in What'Best) for comparison of results.

Primarily the ministry has to set a standard response time. After their first call, applicants should be able to expect an ambulance after certain known minutes, which is the standard. To achieve this objective the ambulances must be taken out of the hospitals and be located in an optimal place. This optimal location can *minimize* the total distance traveled from the ambulance center to patients (which is of primary importance), and hence shortens the *response time*. A simple mathematical model (distance formula) can be built to serve this purpose and implemented in Excel add-in software called Premium Solver Platform as seen in Figure IV-7, or What'sBest as in

Figure IV-8. If the ambulance center is approximately located in the coordinates (4.46, 2.77) the maximum distance from the farthest location to the ambulance center will be minimized to what is now approximately 3.5 km., as opposed to approximately over 6 km from the hospital. However, this is not the final solution that has to be implemented as is. After solving the mathematical model, some factors, like population density, historical frequency of demand, and equity also have to be taken into consideration, before the decision of relocating the ambulance station is made.

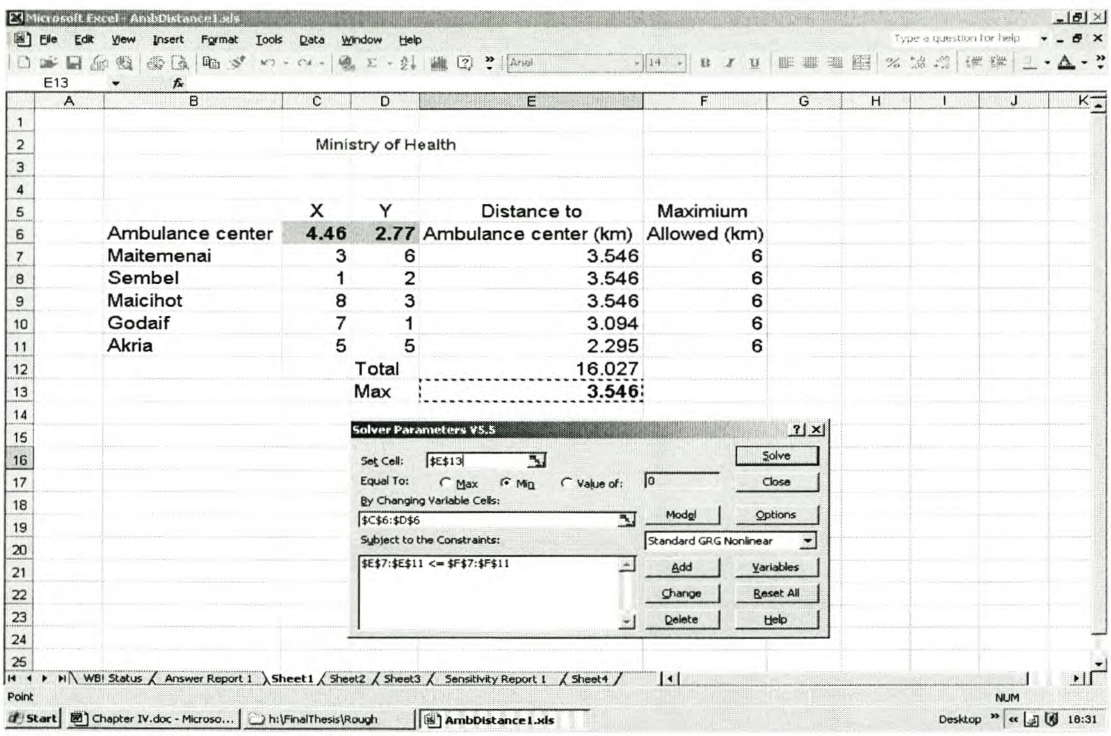
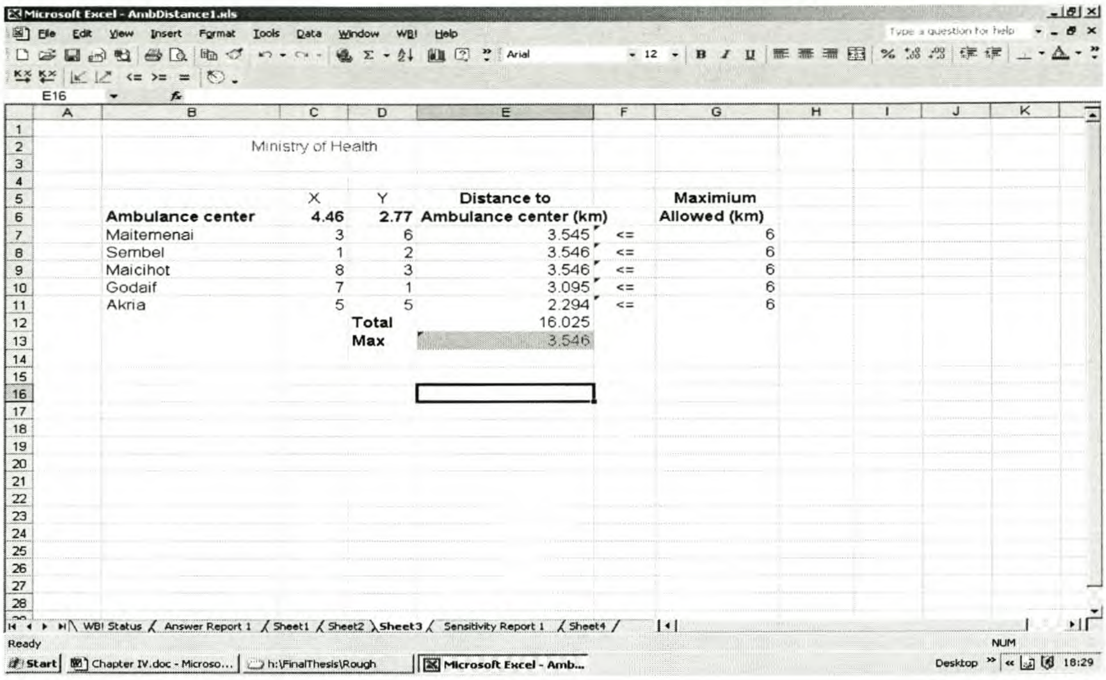


Figure IV-7. Optimal solution to the ambulance location, minimizing the maximum distance in Premium Solver Platform version 5.5.



Ministry of Health

	X	Y	Distance to		Maximium
Ambulance center	4.46	2.77	Ambulance center (km)		Allowed (km)
Maitemenai	3	6	3.545	<=	6
Sembel	1	2	3.546	<=	6
Maicihot	8	3	3.546	<=	6
Godaif	7	1	3.095	<=	6
Akria	5	5	2.294	<=	6
		Total	16.025		
		Max	3.546		

Figure IV-8. Optimal solution to the ambulance location, minimizing the maximum distance by What'sBest.

The importance of facility location is more critical if it involves human life. ReVelle (1991) emphasizes this by asking if a computer can save lives. He concluded that it can, if it aids in the more efficient siting of fire equipment and ambulances, both limited resources. Two decades of remarkable growth in the ability to site emergency services is being further advanced by bringing the powerful supercomputer to bear on these theoretically challenging and computationally intensive public problems. In Figures IV-7 and IV-8, the optimal ambulance location is solved by the ubiquitous software, Excel. This technique can also be used by the Ministry of Education and the Ministry of Health respectively to locate schools, and health facilities in the countryside to serve many scattered villages. Where to locate and why at a specific site is a decision that affects the daily lives of the public.

d) Decision support system

Regarding software, the Ministry of Education uses SPSS for data analysis. In addition, though not so far implemented, they have trained officials for CSPro (census and survey processing). According to Ngopya (2001), CSpro software is a system for designing and running applications which perform data entry, cross-tabulation and mapping of census and survey data. However, as Ngopya states CSPro has the following limitations:

- The user must have a strong programming background in order to understand the CPSPro language.
- The user has to write a small application for any task to be performed;
- CSPro is unable to read spreadsheet of data base files. It can only read ASCII data files;
- CSPRO is unable to produce charts or to perform statistical calculations; and
- CSPRO is unable to convert output tables into HTM, this files are necessary for publication on the Internet.

CSPro is provided free of charge at request from the U.S. Bureau of the Census or can be downloaded free of charge from http://: www.census.gov/ipc/www/imps. However, given the limitations of CSPro and level of computer expertise in Eritrea, it will not be easy to apply.

For population projection the Ministry of Education uses software called People which widens the scope for more detailed projections. However, population projections alone are not sufficient and cannot supersede human resources planning. The number of teachers available for the coming years does not depend only on the forecasted number of students, but on all factors affecting the availability of teachers. The number of teachers available at a certain time is determined, amongst others, by the current age of teachers, rate of sickness and death, quitting rate, and the pool of new entrants. Based on these statistics, the Ministry has to determine not only future human resource requirements but also the means to obtain those requirements (objectives) given the volatile situation of the region.

In the Ministry of Health PHARMECOR is a parastatal that imports and distributes pharmaceutical and medical supplies to the private and government pharmacies and hospitals in the country. As the activities of PHARMECOR are more related to inventory management, the author has focused on this aspect of the organization to find out the effects of item perishability that is disregarded in many inventory systems.

PHARMECOR does not employ an Economic Order Quantity (EOQ) model to decide its reorder point. Instead the management has developed heuristically a limit of *when to order* based on prevalence of disease, immigrants, and added health facilities. In addition the organization has software called PeachTree as a decision support. This software is used for:

- Inventory control systems
- Invoicing
- Forecasting
- Warning of minimum inventory level

The inventory system is considered successful when the damaged and expired stock is taken into account. The management of PHARMECOR indicates that in the year 2001 the expired medicine was only 0.07%, and the damaged materials 0.007% of the total stock. Though they sometimes run out of stock and experience shortages of certain medicines and instruments, it is not because of the weakness of their operations but is attributed to the shortage of foreign currency that it acquires from the government.

Even though PHARMECOR knows when to order and the reported damaged materials are negligible, this situation must not lead to complacency. This is not a guarantee of minimizing cost. To minimize cost it has to know how much to order at a time, and to take into account the inventory holding cost, because holding an inventory involves various costs, including storage, insurance, and spoilage.

4.5. The Ministry of Agriculture

The influence exerted over the current conditions of Eritrea by the protracted armed struggle can hardly be overemphasized. Eritrea emerged at independence with a depleted and damaged stock of infrastructure, the result of direct hostilities and of the indifference of the occupying regime to Eritrea's modern development. With this background projects for development become one of the priorities of the country. Since independence the Ministry of Agriculture has been running many projects all over the country and committing huge financial resources. The author visited the

Ministry to explore if there are applications of scientific project management techniques and DSS.

To show the magnitude of the financial outlay, the cost of the Eastern Lowlands Wadi Development Project can be taken as an example. According to the International Fund for Agricultural Development (1995:40), the cost of this project was budgeted to be USD 16.6 million. This is only a small example of the programs run by the ministry all over the country. Despite all these financial investments, proper project techniques have not been applied, resulting in cost overrun and delays. The Eastern Lowlands Wadi Development Project is one example of a projects that did not meet their schedules. As a consequence of delays, Eritrea has been obliged to pay commitment charges to the donors.

Generally, in the area of project management in relation to OR/DSS, the main weaknesses identified have been regarding:

a) *Identification of project cycle*:

Projects operate as part of a system and involve uncertainty. Hence, it is good practice to divide projects into several phases. Cusworth and Franks (1993:5) indicate that though project phases vary by project or industry, most models of project cycle have the same basic concepts and are highlighted by the stages: identification, formulation, implementation, commissioning, operation and evaluation. Despite their wide use, these basic steps have been overlooked by the Ministry. It was only in the year 2003 that the Ministry decided to introduce standard project preparation, appraisal, approval, implementation and evaluation procedures to be followed by all departments and administrative regions (Ministry of Agriculture, 2003). To this end, a project planning manual has been developed. This is long (about a decade) after the ministry has started to run many projects without proper OR (project management) techniques. Schwalbe (2000:25) argues that the project life cycle approach provides better management control and appropriate links to the ongoing operations of the organization. As mentioned above the absence of project management techniques led to project failures which involved high opportunity costs. The tied up capital and labor, which could have been productive elsewhere, and the opportunity cost of the intended (but not achieved) products and services are not difficult to imagine.

b) Assignment of responsibility

One of the fundamentals of project management is dividing the work into packages and the assignment of responsibility to individuals. Dividing the project into work packages makes it possible to prepare project schedules and cost estimates and to assign management and task responsibility (Nicholas, 2001:165). Every activity has also to be labeled as critical or normal. Unless some of the activities are identified as critical and special attention is given to them, there will be a delay in the overall project completion time. In the ministry, in many cases, no specific person has been taking responsibility of a work package from the beginning up to the end, and critical activities have not been identified and prioritized. Because of the shortage and relocation of staff, proper assignment of personnel has not been done, resulting in a standstill and backlog of activities that could have been finished on time.

c) Multidisciplinarity

Multidisciplinarity is at the heart of development. Unless development projects are tackled by a multidisciplinary approach the solution they seek will be far from sustainable. Multidisciplinarity does not only mean the integration of disciplines within one ministry, but it also means a cross-fertilization of ideas from across different sectors and society at large. However, in the aspect of project management, the approach of the Ministry of Agriculture has not been multidisciplinary and its organs have been working in isolation in a top down manner. The ministry has also realized that there has been lack of consistency among the various departments and administrative regions in the process. Consequently, the huge investment made by the government to implement wide ranging agricultural projects failed to bring about the desired impact on the livelihood of farmers. One of the contributing factors to this failure is the absence of OR .

d) Decision support system

It is very difficult to schedule and control big projects such as run by this ministry without the aid of electronic tools. Though they use Microsoft Excel, it cannot fulfill the required functions. The ministry has Microsoft Project 98; however, it is not applied and cannot be applied, because Microsoft Project only functions if there is proper work break down and clear assignment of responsibility to individuals against a specified time frame. These aspects have not been practiced in the ministry since independence.

Schwalbe (2000:405) emphasizes the need for Microsoft Project 98 by stating that it is a software that can assist users with different aspects of all nine project management knowledge areas (integration, scope, time, cost, quality, human resources, communications, risk, and procurement). Mostly managers use it for project control and tracking, detailed scheduling, early project planning, communication, reporting, high-level planning, Gantt, CPM, and PERT. Had the Ministry of Agriculture applied PERT/CPM techniques, it would have been forced in some way, to plan its projects ahead and tackle bottlenecks before they were aggravated.

Finally, it has been identified that the Ministry of Agriculture has been working on programs. However, this approach precludes the focus on the activities and makes it difficult to monitor and evaluate specific projects. For tangible results the ministry has to be focused by adopting a project approach. It is only through the project management approach that the goals of programs will be achieved.

4.6. The Ministry of Fisheries

According to the International Fund for Agricultural Development (1995:3), the fisheries industry in Eritrea was very active in the 1950s, but production is very low at present with much of the infrastructure having been destroyed and/or in need of severe rehabilitation. The catch is estimated to be in the region of 4000 tons per annum, but it is believed that there is a potential for 70,000 tons to be harvested annually from the Eritrean part of the Red Sea.

a) *Model for sustainable fishing*

The author attempted to find out if the ministry determines the annual allowable (optimal) mix catch, in order not to reduce the fish stock below some viable level. This is a multiple criteria decision-making problem. They need to maintain the balance between clashes of socio-economic and environmental goals, ecological, conservation, and short and long-term goals.

The exploitation of the resources to its maximum sustainable level requires among other things the availability of human resources with the skills and abilities to meet the management of resources requirements and the production and marketing conditions. However, currently there is a critical shortage of skilled and semiskilled as well as unskilled manpower in the sector. If the current fishing practice continues, long-term risk cannot be foreseen because the present yield is still suboptimal. It is because of this situation that the Ministry sees the current fishing practice as not detrimental to the stock. Fishing at more than the current level to the point where it is ecologically sustainable is a desired practice to benefit the present generation without compromising the needs of future generations. The point is up to what level and which species?

For this, the ministry has to develop a model for sustainable fishing that does not endanger species biodiversity. Care must be taken not only on the quantity of fish caught, but also on the variety of species. The size of some species may decrease more quickly than the size of others as a result of uncontrolled fishing practices, causing ecological imbalance and biodiversity loss. A suitable and relevant model serves to guard against such potential disaster. So far the Ministry of Fisheries has not yet developed its own model for maximum sustainable yield (MSY). The reason given is that it needs ten years' data to build such a model, which they have not yet collected. Instead, it has adopted an international model built for the estimation of maximum sustainable yield. The linear mathematical model (Schaefer model) the ministry uses, is based on tropical waters, as Eritrea is a tropical country. However, the problem with international models is that they are too general for practical uses. According to the model, given a certain level of effort in tropical water, the quantity of fish is predicted to be a certain amount. Despite this prediction, the fishermen in Eritrea complain that they could not harvest the predicted amount. Though the problem has not been identified, the reasons can be either that the technology employed is backward and the level of expertise is low, or that the international model is too general to apply in Eritrea. In any case the development of a country specific model is imperative, otherwise the estimation of the fishing stock will remain unreliable, affecting potential investment by creating doubts.

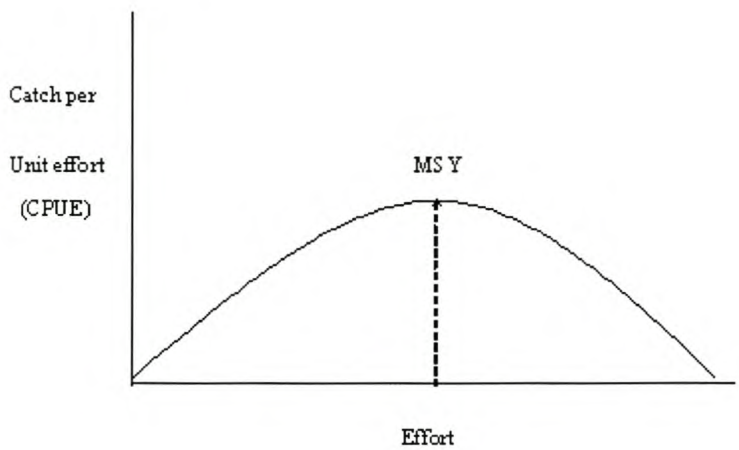


Figure IV-9. Relationship between CPUE and Effort

The curvilinear relationship in Figure IV-9 shows that there is a limit to the maximum sustainable yield as effort (such as number of vessels, vessel hours, man hours, man days) increases. As effort increases the number of fish caught increases at a decreasing rate up to the point MSY. However, if effort goes beyond the point indicated by MSY, the catch per unit effort will decrease and the practice will negatively affect the fishing stock. It is this level (the point at MSY) that the ministry has to attain and it is safe so long the quantity is within that limit for every variety of fish.

The ministry is making use of GIS and had its data captured in 1992-1996 by the aid of the Overseas Development Agency. GIS is of great benefit, helping the ministry to locate the required fishing zones in terms of availability.

b) *Solution by multiple objective linear programming*

A problem that may be faced by the Ministry of Fisheries is presented here to indicate how a multiple objective problem can be solved in a spreadsheet which can be a good instrument of decision-making. The data are hypothetical, and this is only to show the application of multiple objective linear programming (MOLP) in the public sector. This problem cannot be handled by linear programming because it is not unidimensional. The objectives that must be addressed by multiple objective optimization techniques are many. The mathematical aspect of this solution only gives clues to optimality and it should be viewed in the wider context of the decision-making process. The decision is a trade-off between objectives and should not depend on the mathematical solution only.

The Ministry of Fisheries is forecasting the additional demand for some fish for the coming year. Specifically their projections indicate a 600 tons increase in the demand of crayfish, a 700 tons increase in the demand for tuna, and a 550 tons increase in the demand of sardine. These varieties are fished in the Northern and Southern Red Sea. Due to the shortage of employees the fishing industry cannot hire additional workers; instead they schedule extra shifts once a week at a time for the existing workers and fishing ships. It costs the fishing operation 2700 Nakfa[4] per week in the Northern Red Sea, and 2400 Nakfa in the Southern Red Sea in extra shifts. The amount of fish caught in every shift (week) in each location of the sea is summarized as follows.

Type of fish	Northern Red Sea	Southern Red Sea
Crayfish	18 tons	15 tons
Tuna	10 tons	22 tons
Sardine	35 tons	13 tons

Table IV-3. Summary of fish caught in Northern and Southern Red Sea.

The methods used in fishing involve risks of life and ecological degradation. Because of the wear and tear of the ships, for every additional shift (once a week) 240 liters of oil is spilt in the Northern Red Sea, and 150 liters in the Southern Red Sea which pollutes and degrades the ecology. Additionally, in every shift of fishing operation occurs 0.09, and 0.03 life threatening accidents occur in the Northern and Southern Red Sea respectively.

The ministry's objectives are to minimize financial cost, minimize oil spillage, and minimize the expected number of accidents. These three different objectives, and constraints would be formulated as follows:

[4] Eritrean currency

Minimize: $2700X_1 + 2400X_2$ (Fishing cost in Nakfa)

Minimize: $240X_1 + 150X_2$ (Oil spilt in liters)

Minimize: $0.09X_1 + 0.03X_2$ (Accidents)

Subject to:

$18X_1 + 15X_2 \geq 600$ (Crayfish required)

$10X_1 + 80X_2 \geq 700$ (Tuna required)

$35X_1 + 13X_2 \geq 550$ (Sardine required)

$X_1, X_2 \geq 0$ (nonnegativity conditions)

X_1, X_2 are integers

Multiple objective linear programming provides a way to analyze LP problems involving conflict with one another. In this problem we are required to increase production (catch) in order to meet the demand by increasing operations (shifts); on the other hand the increase in operations results in increased cost, oil spillage and accidents. We need to find out when all these constraints and optimality conditions are satisfied. The procedures of MOLP problems are highly iterative and interactive and allow decision-makers to analyze the trade-offs among the various goals and objectives at different possible solutions.

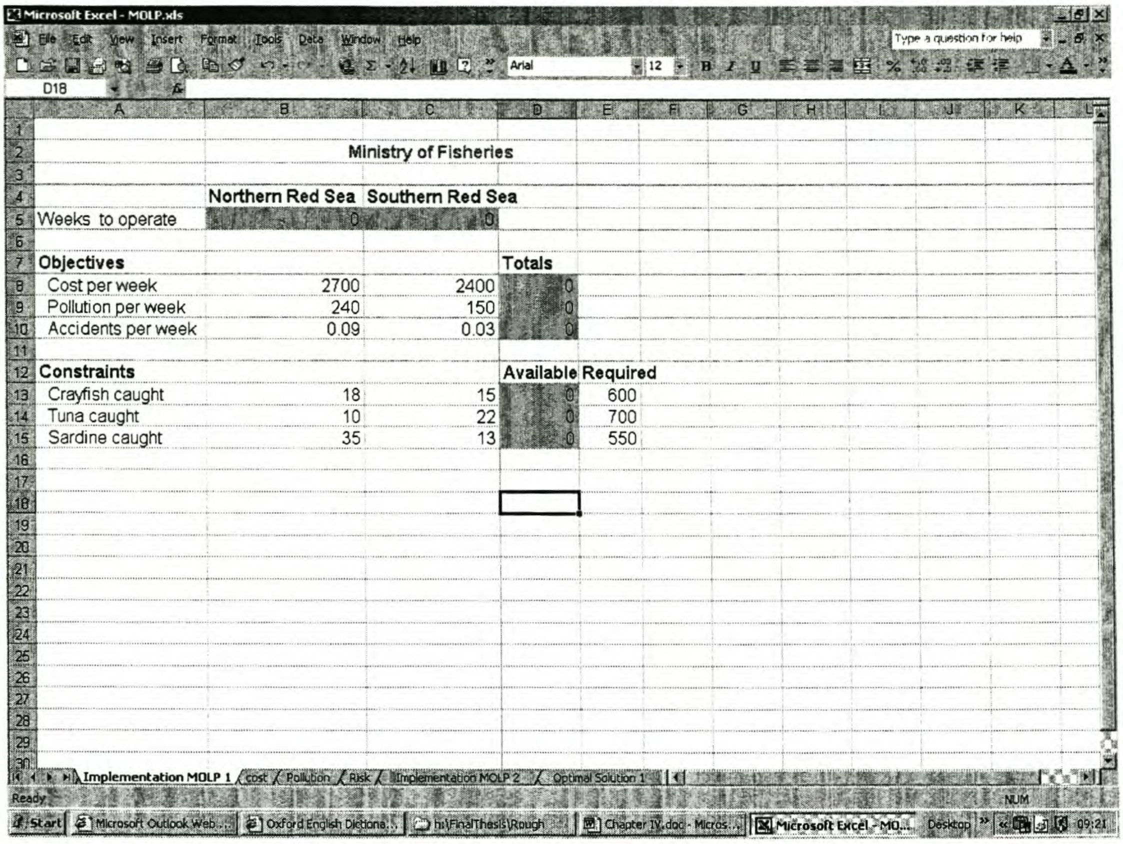


Figure IV-10. Spreadsheet (Premium Solver Platform version 5.5) implementation of the MOLP.

To find a solution we need to formulate the problem (Figure IV-10) and to calculate target values for the objectives, i.e. first we have to minimize fishing costs (Figure IV-11), oil spillage (Figure IV-12), and accidents (Figure IV-13).

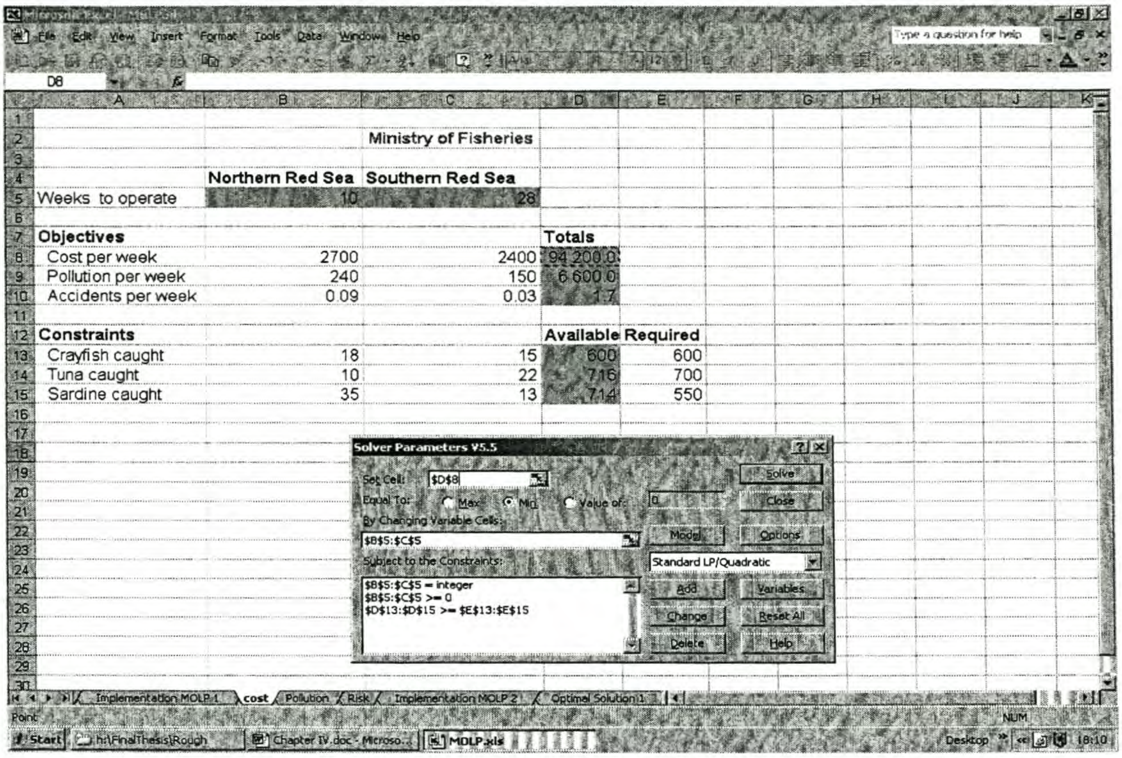


Figure IV-11. Optimal solution when minimizing fishing costs.

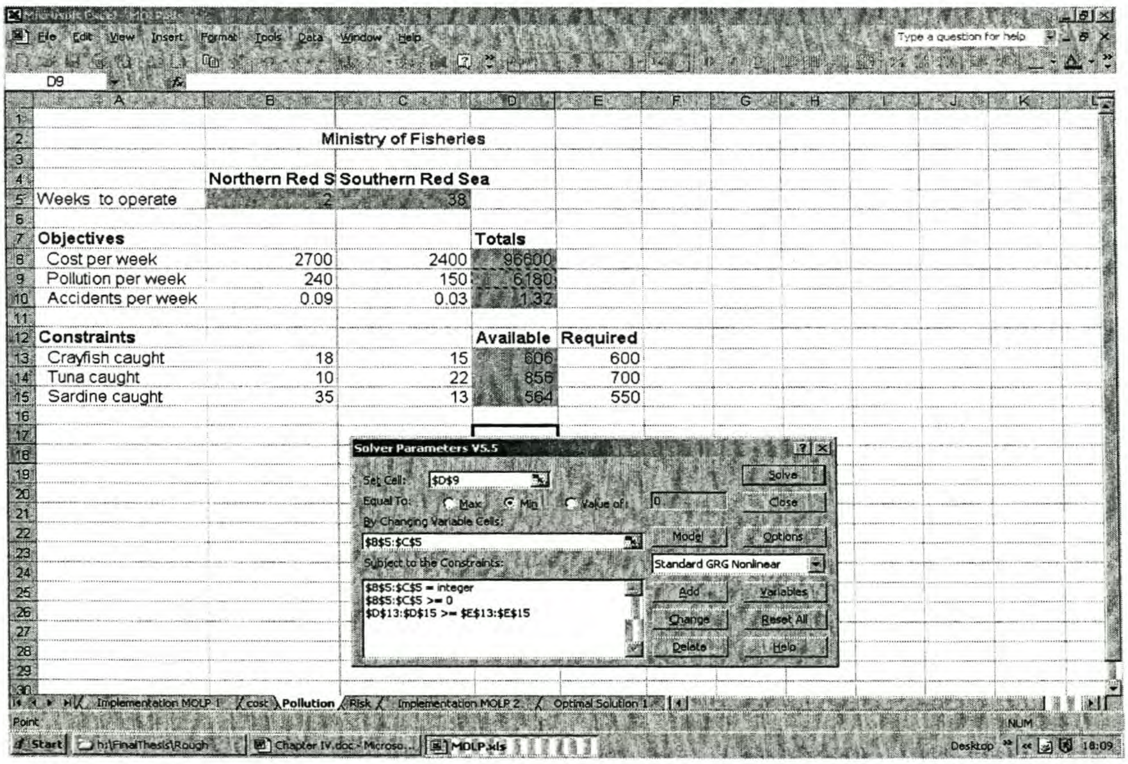


Figure IV-12. Optimal solution when minimizing pollution per week.

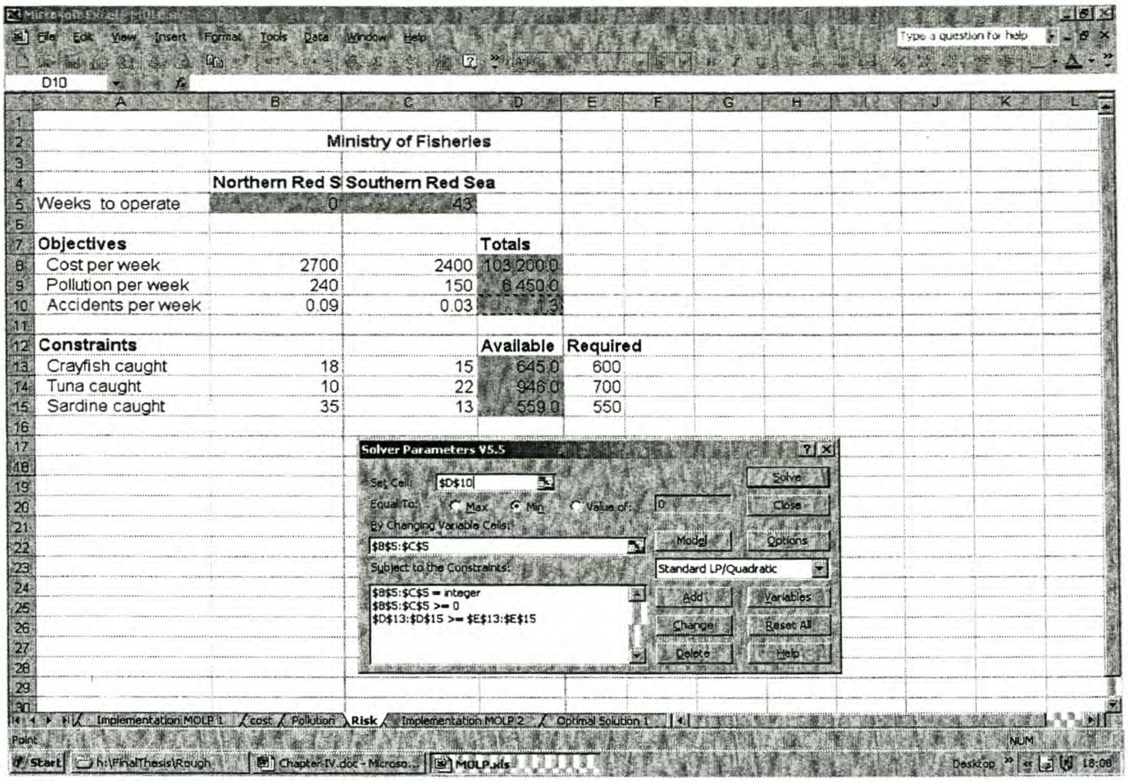


Figure IV-13. Optimal solution when minimizing accident.

If we optimize solutions for the fishing costs, oil spillage, and accidents, it means that we have found target values (goals) for the three objectives. That is:

- The minimum fishing cost (9600 Nakfa) is Goal 1.
- The minimum oil spillage (6180 liters) is Goal 2.
- The minimum number of accidents (1.3) is Goal 3.

These are goals with target values (the minimum values in Figures IV-11, IV-12, and IV-13), which can be taken as soft constraints. We have to minimize the percentage deviation from targets in accordance with the agreed weights given to the objectives. Therefore, the problem has to be rewritten in the format of goal programming as shown below.

Minimize: D (where D is the weighted percentage deviation)

Subject to:

$$18X_1 + 15X_2 \geq 600 \text{ (Crayfish required)}$$

$$10X_1 + 22X_2 \geq 700 \text{ (Tuna required)}$$

$$15X_1 + 13X_2 \geq 550 \text{ (Sardine required)}$$

$$w_1(2700X_1 + 2400X_2 - 9600)/9600 \leq D \quad \text{(Goal 1 MiniMax constraint)}$$

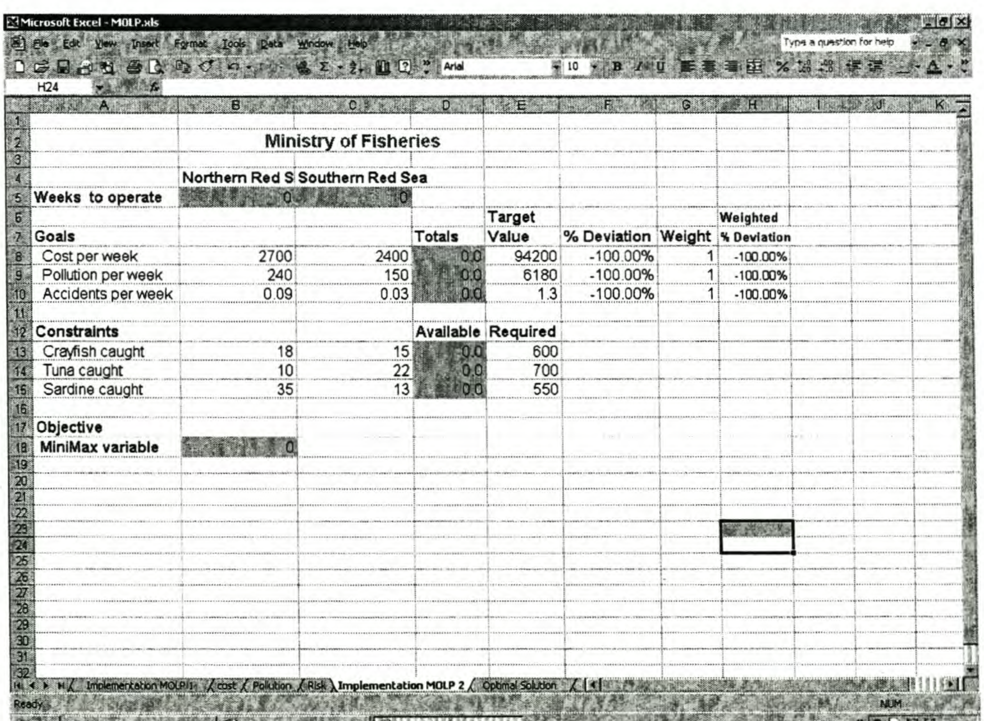
$$w_2(240X_1 + 150X_2 - 6180)/6180 \leq D \quad \text{(Goal 2 MiniMax constraint)}$$

$$w_3(0.09X_1 + 0.03X_2 - 1.3)/1.3 \leq D \quad \text{(Goal 3 MiniMax constraint)}$$

$X_1, X_2 >= 0$

X_1, X_2 are integers

w_1, w_2, w_3 (weights given) and are positive constraints.



Microsoft Excel - MOLP.xls

	A	B	C	D	E	F	G	H
2		Ministry of Fisheries						
4		Northern Red S	Southern Red Sea					
5	Weeks to operate	0	0					
6					Target			Weighted
7	Goals			Totals	Value	% Deviation	Weight	% Deviation
8	Cost per week	2700	2400	0.0	94200	-100.00%	1	-100.00%
9	Pollution per week	240	150	0.0	6180	-100.00%	1	-100.00%
10	Accidents per week	0.09	0.03	0.0	1.3	-100.00%	1	-100.00%
12	Constraints			Available	Required			
13	Crayfish caught	18	15	0.0	600			
14	Tuna caught	10	22	0.0	700			
15	Sardine caught	35	13	0.0	550			
17	Objective							
18	MiniMax variable	0						

Figure IV-14. Implementation of goal programming model to analyze MOLP.

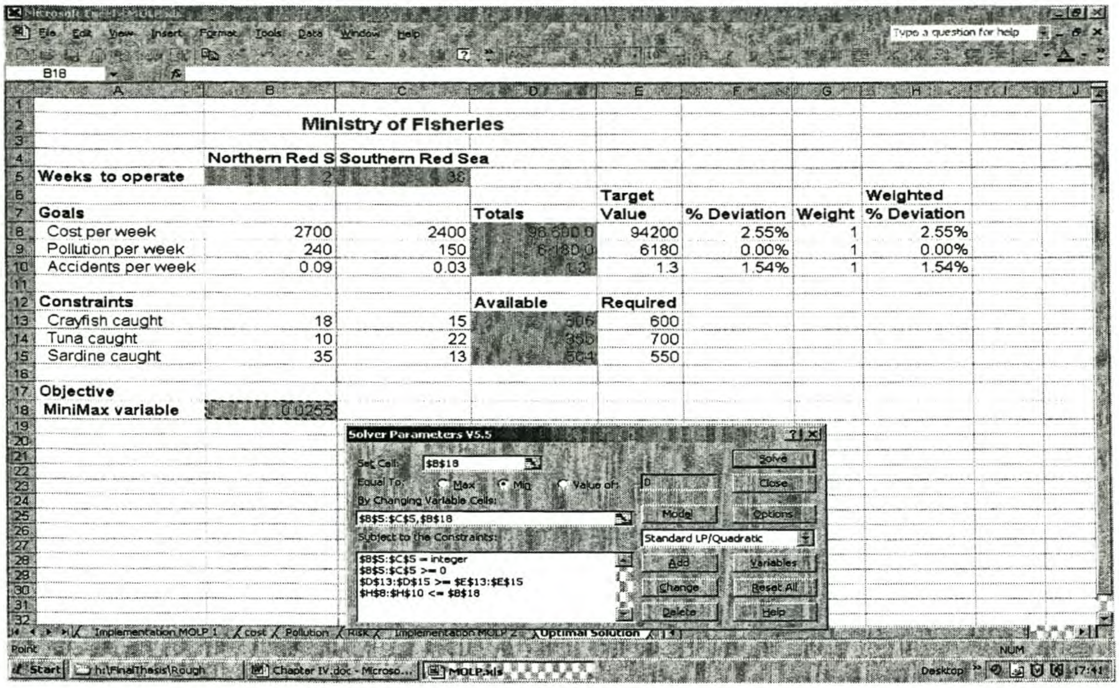
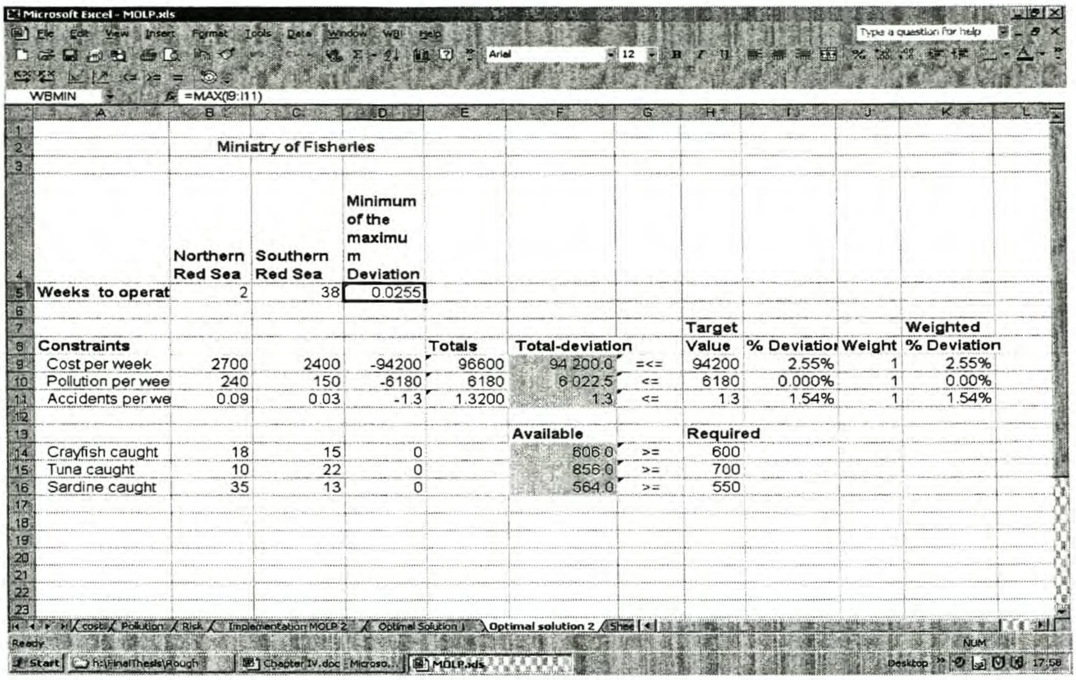


Figure IV-15. Optimal solution to the MOLP problem through goal programming.

Here the weight is taken to be one, and it can vary according the decision-makers preferences, initially and during sensitivity analysis.

The solution, in Figure IV-15 is also implemented in What's*B*est software as shown in Figure IV-16. The results obtained by both software, and their user-friendliness and affordability are similar.



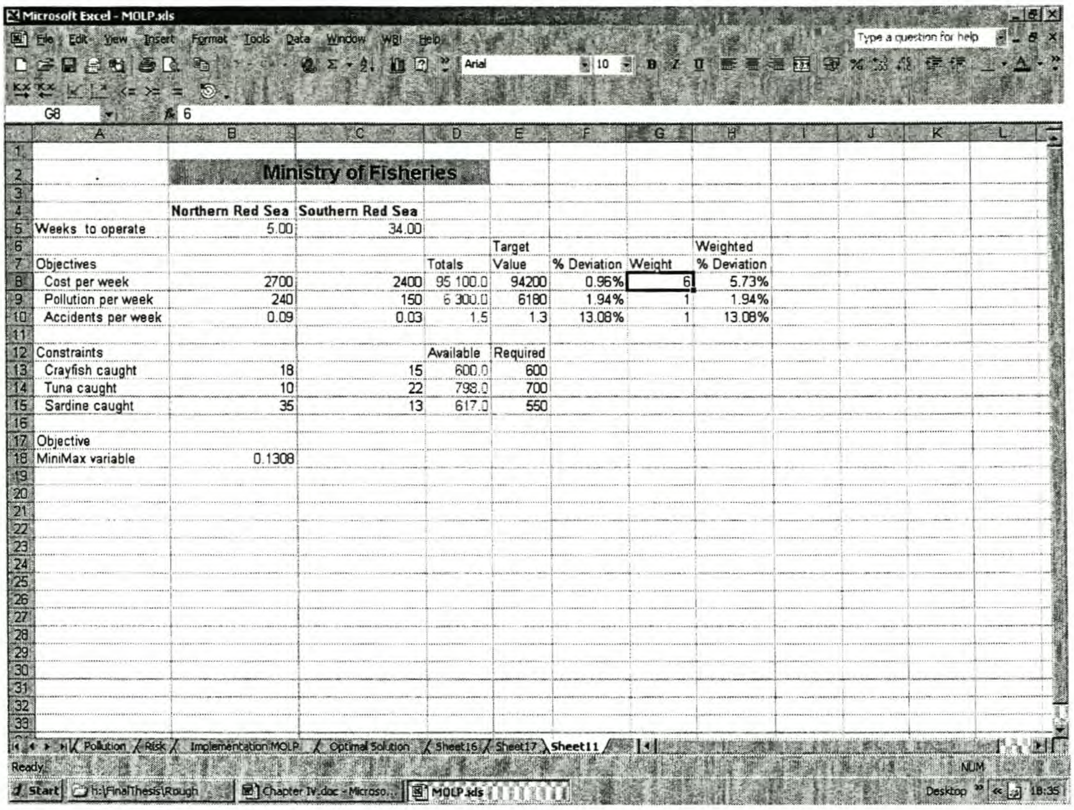
WBMIN =MAX(I9:I11)

	Ministry of Fisheries									
	Northern Red Sea	Southern Red Sea	Minimum of the maximum Deviation							
Weeks to operat	2	38	0.0255							
							Target			Weighted
Constraints				Totals	Total-deviation		Value	% Deviatio	Weight	% Deviation
Cost per week	2700	2400	-94200	96600	94 200.0	=<=	94200	2.55%	1	2.55%
Pollution per wee	240	150	-6180	6180	6 022.5	<=	6180	0.000%	1	0.00%
Accidents per we	0.09	0.03	-1.3	1.3200	1.3	<=	1.3	1.54%	1	1.54%
					Available		Required			
Crayfish caught	18	15	0		606.0	>=	600			
Tuna caught	10	22	0		856.0	>=	700			
Sardine caught	35	13	0		564.0	>=	550			

Figure IV-16. Optimal solution to the MOLP problem through goal programming (in What'sBest).

The solutions indicate that in the coming year there should be 2 weeks of fishing in the Northern Red Sea, and 38 weeks in the Southern Red Sea at a cost of 96,600 Nakfa. This operation results in 6180 liters of oil spillage, and 1.3 accidents. These are the minimum amounts of all cost, ecological degradation and accidents which bring about the optimal amount of fish to be caught to satisfy the demand as shown in Figures IV-15 and IV-16.

Given that all objectives have equal weights the solution is within approximately 2.55% of achieving the target solution for goal 1, 0% for goal 2 (that is fully achieved), and 1.54% for goal 3. Using other weights would produce different solutions. As the relative weight ascribed to a goal increases the solution is driven closer to achieving the target value for this goal. For instance, if the weight for the target value cost per week is increased to six, the percentage deviation decreases to 0.96% (as opposed to 2.5%, when its weight was one). This implies that more relative weight is given to the target we want to prioritize (see Figure IV-17). However, it may not be optimal, as in this example the percentage deviation (13% as opposed to 2.55%) falls further short of achieving the overall objective, that is, it is more deviated from the target.



	Ministry of Fisheries						
	Northern Red Sea	Southern Red Sea					
Weeks to operate	5.00	34.00					
				Target			Weighted
Objectives			Totals	Value	% Deviation	Weight	% Deviation
Cost per week	2700	2400	95 100.0	94200	0.96%	6	5.73%
Pollution per week	240	150	6 300.0	6180	1.94%	1	1.94%
Accidents per week	0.09	0.03	1.5	1.3	13.08%	1	13.08%
Constraints			Available	Required			
Crayfish caught	18	15	600.0	600			
Tuna caught	10	22	798.0	700			
Sardine caught	35	13	617.0	550			
Objective							
MiniMax variable	0.1308						

Figure IV-17. Solution when cost per week is given more (6 rather 1) weight.

The MOLP technique is of wide spread application in the public sector to study the trade-offs among the objectives in order to find a solution that is the most desirable to the decision-makers. Most public sector problems are multi objective in nature with many constraints. According to Rardin (1998:373), applications in the public sector must be treated as multiobjective. When goals cannot be reduced to a common scale of cost or benefit, trade-offs have to be addressed. Only a model with multiple objective functions is satisfactory, even though analysis will almost certainly become more challenging. Goal programming is the most commonly employed technique for dealing with multiobjective settings.

4.7. The Commercial Bank of Eritrea

The Commercial Bank of Eritrea is a government owned financial institution that operates through its branches in all the six *Zobas* (administrative regions) in Eritrea. The researcher visited the main branch in Asmara (the capital city) and attempted to assess the status of

OR/DSS in relation to information systems, models, and loan application screening methods.

The information system in the main branch is limited to only transactional purposes—like capturing data, calculating interest rates, and preparation of balance sheets and bank statements. There is no network between the back and front offices within the main branch, which challenges the efficiency of operations. They don't have any decision support software except those that serve for transactions.

To facilitate loan approval, the bank has a standard form comprising loan eligibility indicators (see Annexure B & C). Although the loan approval form has many criteria for decision-making the bank processes them manually. This manual processing, apart from being inefficient, is likely to be influenced by subjectivism. The more the number of applicants and criteria increase, the more the decision-making process is delayed until it becomes unreliable. In the current situation where investors and loan applicants are increasing, traditional ways of processing applications may hinder development objectives. To keep pace with these objectives and treat applicants objectively, equitably and transparently, the bank needs loan application screening software such as NeuNet Pro 2.3.

Moreover, optimization models are some of the techniques that are relevant for the bank's operations as well. As a bank it has a legal and ethical obligation to avoid hazards. Though not a pure profit maximizing entity, it also must make profit for its sustainability and expansion. For these and other multiple objectives, it is helpful to have an optimization model for the decision of levels of interest rates and lending policies. So far, the bank has not developed such models.

Other factors affecting the efficiency of the bank's operations are manifested by the intolerable everyday queues in the bank. People going to the bank for routine transactions have to join a long queue which is a daily phenomenon in all branches of the commercial bank. According to the bank officials, the average waiting time is 45 minutes, sometimes even more. Though they cannot get rid of queues, they have to try to reduce the adverse impact of waiting to an acceptable level. This can be improved by increasing the service stations (according to queuing models), training of personnel, and instituting a network between the back and front offices.

4.8. The Grain Board

The Eritrean Grain Board is a public institution responsible for buying, storing and selling grain to the people at relatively lower prices in order to stabilize fluctuation and control undue exploitation by merchants. To fulfill its mission the Board has its own stores at Zigb (main store), Dekemhare, and Asmara. In addition it has also rented other stores. The main focus of the researcher has been to see if the decision made to locate the storage facility at Dekemhare is optimal. Currently locational decisions in Eritrea are of high importance because the country is in its rehabilitation stage where many new sites for facilities are to be determined. This calls for appropriate tools and techniques. According to Current, Daskin & Schilling (2002:81), the ubiquity of locational decision-making has led to a strong interest in locational analysis and modeling within the OR and management science community.

The Board identifies that long term storage facilities have the following characteristics:

- The ability to adjust and maintain the grain at a temperature below 17^0 C; and
- The equipment and knowledge needed to predict problem situations before they develop, and to prevent loss of quality or quantity of grain through fumigating, drying, or cooling the grain.

Moreover, the variables for the decision of where to locate a grain storage facility include:

- Aeration
- Distance from port (as 80% of the grain is imported)
- Distance from customers

The climatic conditions which allow the objectives to be met exist only at higher elevations in Eritrea like the cities of Asmara and Dekemhare. Dekemhare, which is in the highlands, is only 130 km away from the port of Massawa. In addition it is not far from consumers and it is optimally situated for ease of distribution.

However, the author identifies problems concerning the specific location of the facilities within Dekemhare. The specific location of the stores is in an area which was used for agriculture. Up to the mid of 1970s, before its operations were disrupted by the war of liberation, the Italian investors used to export fruits and vegetables grown on this farmland. But, the new Eritrean government inherited this farmland as fallow land with its entire infrastructure dismantled. It is in this situation that the Eritrean Grain Board located its storage facilities, based on the above mentioned criteria.

The decision to locate a facility is a multiobjective problem that affects many stakeholders and must not be made alone even if it satisfies the physical criteria specified by one sector. According to Current *et al.* (2002:81), location decisions are strategic in nature. That is, they involve large sums of capital resources and their economic effects are long-term. In the public sector they influence the efficiency by which jurisdictions provide public services and the ability of these jurisdictions to attract households and other economic activity; in addition they frequently impose economic externalities. Such externalities include pollution, congestion, and economic development, among others.

If the decision made to locate the facility in that specific location is analyzed on the basis of the above argument, lack of multidisciplinarity approach in the decision-making process becomes evident.

a) *Environmental issues*:

The main problem with the location of the facilities can be considered as an environmental problem. After the stores were built, the contiguous area was zoned as industrial and many factories have been established since then, as it is plain and suitable for such installations. However, there are emissions from the factories that can pollute the stored grain, as the stores are adjacent to the newly built factories.

Furthermore, the sound pollution created by trucks going to and fro is unbearable to the students and staff, because the stores are next to the sole secondary school in the town. The trucks also have to cross many residential areas causing sound and air pollution, and visual intrusion. The pollution is also aggravated by the dust caused by the trucks as the road near the school is not asphalted.

b) *Economic considerations*:

As mentioned above, the site was modern farmland creating jobs for the local people and a source of foreign currency. Due to the limitation of time, the author could not do cost-benefit analysis regarding the feasibility of the farmland given the shortage of underground water (which was its sole source) in the area. Nevertheless, it can be argued that the Eritrean

Grain Board should not have been in a hurry to invest a huge amount of capital where there is a potential of relocation of the facilities at high cost due to many foreseen factors. The possibility of rehabilitating the farmland cannot not be totally ignored; or the area can rather be zoned for factories or factory warehouses. In either case the costs of relocation are large. Generally, with every increase of alternative use, the opportunity cost of the facilities of being in that place goes on increasing.

c) *Safety*:

As mentioned in the preceding paragraphs, the facilities are situated between the factories and the school. Previously the facilities were outside the town (but near the school), but now the town is expanding and the stores find themselves nearer to the middle of town. This exposes them more to sabotage and fire hazards than if they were in isolated area.

There are many alternative sites around Dekemhare where the Eritrean Grain Board can locate its stores, in the areas with lower opportunity cost. There are barren areas with no alternative uses at least in the near future where the facility could have been located from the onset. Before reaching such a strategic decision the involvement of economists, environmentalists, the community and other sectors of the government are of paramount importance. This can prevent undesirable consequences.

4.9. Chapter Summary

In this chapter, the author has described to what extent the Eritrean public sector makes use of OR and DSS in its decision-making processes for correct policy formulations, and how such systems could be applied. To this end, the author visited seven organizations mainly focusing on the Ministry of Land, Water and Environment.

The Ministry of Land, Water and Environment is one of the ministries in which OR and DSS could find wide applications. In the year 2003, in its effort to distribute land for housing in Dekemhare, the Department of Land experienced public complaints concerning its decisions. Even though the basis of these complaints can be attributed partially to the wide gap between demand and available land, the main problem is the absence of appropriate OR techniques and DSS which must include public participation. As the ramifications of such big issues can well be anticipated, a scientific approach to decision-making should have been implemented from the initial stage.

The Department of Land categorized and gave a quota to applicants according to their social groups and assigned relative weights to the respective criteria and prioritized using Microsoft Access. However, Microsoft Access is a database program and not comprehensive enough and is irrelevant for the purpose at hand. It cannot adequately handle issues such as this which involve multicriteria and sensitivity analysis. In addition, the flaw in the process can be identified in the use of the quota method itself which laid the foundation for competition in narrow groups regardless of the wider context. This method excluded some applicants who deserve to succeed in obtaining land. Moreover, the weights given to the same criteria are not uniform across all social groups. The criteria themselves were not also exhaustive.

One of the OR's foundations is a multidisciplinarity approach to problem solving. The Department did not involve other sectors from various disciplines. The involvement could have added to transparency and satisfaction. In addition, the time between the data collection and the decision taken was more than a year which can affect the scoring of the criteria.

The Department of Land applied Microsoft Access as a decision support. However, Microsoft Access is a database program and not comprehensive enough and is irrelevant for the purpose at hand. It cannot adequately handle issues such as this which involve multicriteria and the required sensitivity analysis. V.I.S.A, which is easily affordable, is suitable for this case. The author has proposed a model with criteria applied across all social groups uniformly that can run in V.I.S.A.

For technical support, the Department of Land makes use of software Autocad, ArcInfo, GPS path finder office, and ArcView GIS in its Land-use planning. The Department of Environment has Green Gas Inventory software to calculate pollutants. However, it does not have a national standard that specifies an optimal level of pollutants that are allowed to be emitted to ensure sustainable development. As pollution does not know borders the Department should be aware not only of the emissions from Eritrea but from other countries, especially from the Middle East, as well. Hence, the low level of pollutants in the country should not be a reason to delay in developing control measures.

The Ministries of Health and Education are other candidates for OR and DSS applications. However, OR is not familiar as an approach to solving problems in these ministries. Optimization is tried to be done, multiple objective problems are solved, decision of facility locations are made by judgment and not OR techniques.

MIS and DSS are in their infant stage. In the Ministry of Health, despite the amplified need, the lack of a developed information system results in duplication of work and loss of financial and time resources. Patients often lose their cards and are registered more than once, because there is no patient identification number. This situation creates a problem when following a patient's case. Similarly, staff waste their time filling in forms instead of focusing on service.

Both the Ministries of Education and Health have networks which connect them with their offices in their respective administrative regions which they use to exchange data. But, their internal systems are not automated and almost everything is done manually.

The Ministry of Health does not have a standard ambulance response time after a first call is made and the ambulances are not located in an optimal location. The author has demonstrated how an optimal ambulance center can be located in the city of Asmara by a distance formula (non-linear programming) technique which can be applied to siting schools and health facilities.

To rebuild the damaged infrastructure, the Ministry of Agriculture has been running large scale projects since independence. In the Ministry, basic project management techniques and procedures have been lacking. The usual models of project life cycle were not in place, and it was only in the year 2003 that the Ministry came to realize this and issue a manual to introduce the standard procedures of project management. The Ministry's focus has been on programs and not on projects. Hence, the non-assignment of responsibility to a specific work package has plagued the Ministry's goal achievement efforts resulting in delays and cost overruns. Moreover, there has not been substantial integration and coordination of efforts from within the Ministry and other sectors, regarding managing projects. Such huge projects can best be directed by the help of specialized software called Microsoft Project which has not yet been applied by the Ministry, despite its presence there.

One of the main responsibilities of the Ministry of Fisheries is to ensure sustainable fishing practices. To enable this, the Ministry has adopted an international linear mathematical model of which its relevance to Eritrea has not yet been confirmed. This calls for the development of a national model. GIS has long been applied in the Ministry for spotting fishing zones.

Like all the others, the Ministry's operations involve multiple objectives. Its objectives include making available fish to meet the market demand, minimizing cost, guarding against ecological degradation, and minimizing accidents. To this end a multiple objective linear programming problem with hypothetical data has been demonstrated in the previous sections. Similar programs can be used in many public sector organizations.

The commercial Bank of Eritrea is the biggest bank in the country. Despite its relatively massive operations, its information system is limited to transactional purposes and its back and front offices are not connected by network. Its loan application forms are processed manually. OR techniques like optimization and queuing models are absent. These could help in the determination of service facilities and solving of conflicting and multiple objective issues including lending policies, legal and ethical objectives, and level of interest rates.

The Grain Board of Eritrea has grain storage facilities in different areas of the country of which one is in the town of Dekemhare. Problems related to the environment, economy, and safety are identified as the result of the decision to locate this facilities in this specific area. A Multidisciplinary approach and the involvement of different organs of the state and community could have prevented these consequences.

Chapter V

Conclusions and Recommendations

5.1. Conclusions

5.1.1. The Nature of Decision Support Systems

Decision-making in which people have to choose the best course of action among alternatives is as old as human beings themselves. To select the best option is not a haphazard activity, but an informed and systematic endeavor that requires education, experience, intuition, judgment, and support systems. As a scientific approach to problem solving, OR aided by DSS give skills necessary to achieve practical results.

Historically OR's focus was narrow and stressed quantitative methods. Now, however, it is moving towards softer approaches to incorporate tradeoffs between objectives and issues of equity. Though mathematical techniques like linear programming, non-linear programming, multiple objective and goal programming, dynamic programming, simulation, inventory, queuing, and forecasting models are important techniques to problem solving, the final success of all phases of the solution process depends on the creativity and experience of the OR team.

A mixed OR team of different disciplines can speak, for example, of physical problems, chemical problems, biological problems, psychological problems, social problems and economic problems. Multitude issues such as the origins of a problem, the values sought, the trends affecting these values, factors responsible for the trends, the public course of events if interventions are not made and courses of action to be taken to achieve more of the desired goals can only be tackled by a multidisciplinary approach. No single decision maker is sufficiently multilateral to tackle all these multitude issues, and to understand the ramifications of proposed solutions on all aspects of the organization, including its internal and external environments. Multidisciplinarity generally refers to an appropriate combination of knowledge from many different specialties- especially as a means to shed new light on an actual problem.

Similarly, it is to the complexity of societal problems that systems thinking develops. The world is a giant complex with dense connections between its parts. We cannot cope with it in that form and are forced to reduce it to some manageable parts (areas) which we can examine separately. Our knowledge of the world is thus necessarily divided into different disciplines, and in the course of history these change as our knowledge changes. It is not nature which divides itself up into physics, biology, psychology, sociology, and the like; it is we who impose these divisions on nature. However, after analysis we need to integrate the knowledge accumulated by the different disciplines and perspectives in order to have a holistic view of the problem and situation. Systems thinking explores expansionistic thinking, an approach that considers the context of a problem before breaking it down into its component parts. Likewise OR assumes a viewpoint from which scientific procedures can be applied to various aspects of an entire problem. This systems approach helps people to have a balanced perspective concerning an organization's components.

Hence, solutions to social problems are not satisfactorily solved by a single discipline or on a fragmented basis and the range of disciplines converging on a single question is increasing. The social usefulness of the social sciences has always revolved around their application to policy, while the physical sciences stayed with physical problems. But now policy advice is not offered by social science alone; there are strong incentives to physical science to enter that field.

However, there may be costs and obstacles associated with the multidisciplinary approach. When analysts come from different cultures, and background with a wide range of views, it may seem difficult to achieve consensus. Different methods, personal challenges, professional and institutional impediments can be some of the reasons for this. Nevertheless, this contradiction is only apparent, in the sense that the disciplines answer different questions, and in many instances they are complementary.

Despite all scientific developments, many real-world problems are not amenable to direct analytical solution by known mathematical techniques, hence the need to resort to heuristics. Heuristic methods are not haphazardly developed, but OR models and techniques are sometimes useful in developing heuristic search procedures. The advantage of a heuristic over an exact optimization algorithm is that it is usually much faster to execute. Even if it does not guarantee optimality, a particular heuristic is followed because it promises, intuitively or from experience, to help in the search for an acceptable solution, and if in the process a better rule is discovered, then the old one is discarded. So, while heuristics problem solving involves the use of currently accepted rules, it may also involve a search for even better rules to replace them. We must bear in mind that as all societal problems cannot be solved by mathematical formula they also cannot be solved by intuition.

Usually a computerized decision support system may be needed for various reasons—for speedy computations, increased productivity, technical support, qualitative support, competitive edge, and overcoming cognitive limits in processing and storage. Another advantage of DSS, is the ability to evaluate many alternatives quickly in a rather objective way. Hence, the DSS should be very user-friendly and their models should be robust, flexible and transparent to the user. In addition, the Internet, and mobile phones can also help wide public participation presenting alternative ideas for informed policy decisions.

5.1.2. Linkages Between Decision Support Systems and Policy Analysis

The complexity of public sector problems call for computer based DSS and this complexity makes the application of OR techniques dependent on the electronic DSS. Practically, all OR techniques result in computational algorithms that are iterative in nature. This means that the problem is solved in iterations, with each new iteration bringing the solution closer to the optimum. The iterative nature of the algorithms typically gives rise to voluminous and tedious computations. It is thus imperative that these OR algorithms be executed by the computer which in turn become sound basis for our policies. According to Foulds and Thachenkary (2001), the power of mathematical programming can be enhanced by incorporating its models and methods within a decision support system; taking advantage of modern information technology. Such a system, containing mathematical programming subroutines, can often be used to answer certain 'what-if' questions and to make suggestions. Compared to mathematical programming alone, a decision support system usually provides greater flexibility, can deal with a far wider range of practical issues, allows for its users' local knowledge and inspiration, and attempts to enhance the powers of its users rather than replacing them by outsiders.

Operations research primarily aims at improving the effectiveness and the efficiency of the processes of decision-making that occur in every segment of society: including industry, banking, agriculture, government, and politics. The distinctive feature about OR is that it commonly makes use of optimization models. From the very start of the 1980s these models have been increasingly integrated with DSS.

The DSS movement grew out of dissatisfaction with two earlier and very successful applications of technology to OR and MIS. OR and MIS could not meet the growing demand of managers for more effective decision support, and make proper use of the expanding capabilities of information processing technology. MIS focused too much on support for structured, rather than for semi-structured or unstructured decision processes. DSS deal with the latter processes and can enhance the role of OR for policy analysis.

Decision support systems can incorporate a wide range of OR techniques. With these features in place, a DSS can handle large amounts of heterogeneous data, offer modeling and analytical capabilities for maximizing and minimizing objectives within given constraints, and provide a variety of reports and graphics designed by the user. They support human decision-making by making it easier for the user to manipulate data, develop models, and build scenarios. In this way, they are supposed to improve the quality of decision-making, especially when there are multiple objectives and multiple trade-offs involved.

Public sector problems are multiobjective, and solutions are either good or bad, not optimal, which makes policy analysis a complex problem. The final decision often rests on political judgment, hopefully aided by an objective and comprehensive OR-based analysis. To help management determine its policy and actions scientifically the discipline of OR, aided by DSS, is of high importance in that it gives a rational basis for management decisions. OR has various quantitative techniques and models to deal with optimization and other problems that can help decision-making and formulating policies at different levels. According to Brynard (2000:162), decision-making has specific significance for public policy-making. This is because public policy-making comprises different decisions.

These Quantitative techniques, like linear programming models, are most effective at the operational level of decision-making. Decisions at this level, with a single objective and relative ease of problem definition, are well suited to linear programming analysis. However, at the policy level there are too many uncertainties for linear programming analysis to be effective. Hence, at higher levels of decision-making, multiple objective programming is more suitable. Moreover, many social and economic problems are nonlinear and have to be dealt with non linear programming.

Moreover, dynamic models are important because they use, represent, or generate trends and patterns over time. They also show averages per period, moving averages, and comparative analysis. In addition, dynamic programming is a future oriented modeling technique that takes into account the effect of current decisions and policies on future periods and adjusts every decision to yield the best overall performance.

Furthermore, OR and DSS help managers to determine the level of service (queuing problems) provided. The objective is to find the optimal service level that achieves an acceptable balance between the cost of providing service and customer satisfaction. There should be a trade–off between the cost of providing service and the cost of having dissatisfied customers if service is lacking.

Similarly, inventory managers are charged with making the following basic decisions which have to be guided by inventory policies: *when* to order, *where* to order, *how much* to order, and *what* the proper logistics are. To answer these questions and manage the inventory effectively, medium to large organizations need sophisticated computer-based DSS.

All public polices deal with the future and, as a result, they are based on forecasts or projections. The forecasts or projections may be implicit or based on naïve extrapolation or ad hoc assumptions. They may be explicit and based on elaborate extrapolations or on behavioral models which are sometimes unreliable. Nonetheless, forecasts are what distinguish reasoned planning from blind action. Without forecasting, we would be totally at sea. These forecasting techniques are the subject of OR and are best implemented by electronic DSS.

All the above mentioned models require some mathematical skills to understand and implement. Many public officials believe they do not have the mathematical training to understand OR techniques; they are uncertain how these can help and they find the information available to them about OR is generally too technical. However, the growing size and complexity of governments and the increasing availability of electronic computers, have led to the gradual adoption of OR as a tool for planning and decision-making. Today many government agencies have permanent staffs and others employ outside consultants to perform OR analysis. Continuing refinement of methods, particularly in concert with further advances in computing, will undoubtedly result in future growth in the application and importance of OR. Decision support systems hold great promise for productivity improvement by enhancing the quality and speed of decision-making by OR professionals and policy makers.

Likewise, when a problem is too complex to be treated by numerical optimization techniques, simulation is usually used. That is, when the problem either cannot be formulated for optimization, the formulation is too large, there are too many interactions among the variables, or the problem is stochastic in nature. Simulation methods are easier to apply than analytical methods. Whereas analytical models may require us to make many simplifying assumptions, simulation models have few such restrictions, thereby allowing much greater flexibility in representing the real system. Once a simulation model is built, it can be used repeatedly to analyze different policies, parameters, or designs.

Projects are basic means of translating policies into action and are best managed through OR techniques and DSS. Successfully completing a project of any size requires a thorough analysis of the tasks involved, assigning of responsibilities to individuals, accurate estimates of the time and resources required, and a good understanding of the physical and logical interdependencies. If the manager keeps on track of all the required steps, a project is likely to be completed on time. However, in some situations there may be a need to complete a project ahead of schedule. In this circumstance we can use linear programming to help determine the least costly way of crashing a project to meet certain deadlines. Various linear programming techniques can be used to analyze CPM networks and determine optimal crash schedules for projects. Moreover, crashing a project can be seen as multi objective linear programming model. Two objectives can be pursued in this crashing model. On the one hand, we might want to minimize the finish time of the project. On the other hand, we might want to minimize the cost of crashing the project.

In general, policy analysis includes and extends the full range of ideas and analytical techniques from OR and systems analysis supported by DSS that integrate intuition, judgment and experiences.

5.1.3. Challenges to Decision Support Systems

The characteristic most distinguishing the OR approach is its use of models. Mathematical models attempt to translate the essential qualities of real-world situations into systems of equations. Nevertheless, manipulating or solving the mathematical models can engender effective strategies or courses of action for the decision maker. The product of an arithmetical computation is the answer to an equation: it is not the solution to a problem. There is no safety in numbers.

Although there is successful application of OR in the technical problems and well-defined organizational issues, there is a relative lack of success when applied to complex social situations. The generic reasons for the failure of quantitative methods as applied to policy-related problems are: interface between technical knowledge and the political process, level of sophistication of the quantitative techniques, timing between the analytical process and the real world dynamics of a policy problem, inadequate and inaccurate data, and various methodological issues. Similarly the impediments to DSS include lack of user demand, lack of system designer motivation and expertise, reluctance to change, and increased risk of failure.

Despite the fact that OR and DSS can be used to solve problems which incorporate factors such as complexity, uncertainty, and conflict, chaos theory suggests that many of our assumptions about the predictability of events are still misplaced. Non-linear holistic ways of understanding phenomena, are held to demonstrate limitations to predictability. Although short-term developments are predictable, long-term evolution emerges unpredictably. This situation is an indication that complexity theories are likely competing (questioning) the powers of OR and DSS. According to Jennings & Wattam (1998:311-312), a chaotic situation is characterized by the absence of regularities which prevent the accurate prediction of what will happen next. An important concept underpinning chaos theory is that of non-linearity. Many of the formal techniques of decision-making rest on assumptions of linearity. On the other hand chaos theory proposes that events can be discrete and that, despite having full information about past events, we cannot predict the future, as the next occurrence follows a pattern different from that of previous occurrences. Fundamental to the concept of chaos is the perspective that many events both in the physical and social world are complex and hence intrinsically difficult to predict with any certainty. This indicates that traditional approaches may lead to erroneous decisions.

5.1.4. The Status of OR and DSS in the Eritrean Public Sector

In the brief survey of the Eritrean public sector, it was found that there is little OR and DSS awareness, which is reflected in the inadequacy of addressing multicriteria decision processes and selection of DSS, improper project management techniques, suboptimal facility locations and service stations, low level of multidisciplinary approach, inapplication of DSS in the banks, and absence of national standards for pollution control. In general, constraints such as lack of capacity, awareness, know-how, and software are common.

Though in many government departments the accounting system is automated, Government Accounting Software (locally produced), MTX, and Fund Accounting Software, other DSS and OR techniques are far from being familiar. In most public sector organizations they are not even known as a concept which makes the organizations devoid of scientific basis and transparency.

The Eritrean war of liberation can be taken as a background to the current decision-making practices. In the field where resources for effective and efficient decision-making were scanty the Eritrean People's Liberation Front members had to resort to heuristics. In the field decisions had to be made in the shortest possible time, even with little information, sometimes on the spot, because of the pressure of the enemy. In the organizations which the author visited, this style of decision-making (inertia) seems to persist even today, despite the availability of some resources on which scientific decisions could be based.

Based on the literature and the current status of the Eritrean decision-making styles, the following recommendations can be made in order to make the public sector competitive and responsive to the public's demands.

5.2. Recommendations

Even though there are areas where we can apply, as demonstrated in Chapter IV, all optimization mathematical programming and electronic decision support tools, they are virtually absent in the Eritrean public sector. Public officials have long since developed methods and values like those used in the war of liberation. The ex-fighters are dedicated with high work discipline. Hard-work is typical of the ex-fighters, but to be competitive, working harder and harder is not the only solution; instead working differently is the best option. Unless OR techniques and DSS are introduced to the decision-making processes, and the public servants' experience is accompanied by a new approach commensurate with the new knowledge economy of the time, all efforts , whatsoever energy is exerted, are likely to be futile. They must not try to fit every problem to their built-in model, but the model must be changed to fit the problem. In general, there should be a paradigm shift in the overall approaches of decision-making processes in the Eritrean public sector that may include the following.

a) *Decision support systems*

In the Eritrean public sector the rate of computer acquisition has been very high. Despite its late independence after which everything had to start from scratch, there are many computers in the public offices. However, these acquisitions were meant only to automate some paperwork processes. At best the focus seems on the development of MIS, but the public service should go beyond that to benefit from DSS.

Given the level of development of manpower and the complexity of economic interactions, Excel Add-in programs, V.I.S.A, Microsoft Project, GIS, loan application screening software (like NeuNet Pro 2.3) and the Internet are some of the decision support and communication tools that can easily be acquired and applied in the Eritrean public sector in terms of cost and user-friendliness. GIS can be linked to optimization modules and can help, among others, in the selection of appropriate sites for school and health facilities, , locating sustainable fishing and mining zones, strategic and tactical defense positions, water sources and identification of catchment areas for feasible dams, and identification of agricultural areas. As a selection criteria the GIS takes into account, including climate, water, optimal distance, and demographic characteristics.

Currently where Microsoft Excel is ubiquitous to the point that they have become the lingua franca of management, they are underutilized in the Eritrean public sector. Excel with all its might has remained idle, and it is mostly used to supplement Microsoft Word. However, the application of Excel add-in programs are very feasible that do not require much investment in terms of acquisition and training. The only problem is to change the mindset of potential users to be convinced and have faith in the superiority of the tools to the limited human mind when making calculations.

In addition the selection of the DSS that are to be applied is important. According to Foulds and Thachenkary (2001), despite the proliferation of PC-based systems, the potential benefits of these systems as aids to decision-making have not been fully realized. While some DSS may have an impact on individuals and organizations, the adoption and acceptance of these systems among decision-makers has been limited. This may be due to the inflexibility in the systems as well as their narrow design. Therefore, it is important to understand the environment of the decision-makers and the type of support they need in order to make effective decisions, and to examine the models appropriate for addressing their problems.

In the Eritrean public sector, group DSS have an added advantage. The ex-fighters who are at the top level of the public service and the policy makers have been working for a long time in the field together as comrades. In such circumstances it is natural that the group decision-making processes to be affected by 'groupthink' and long established dominance by some figures. This situation makes it imperative to apply group DSS to neutralize the negative effect of decisions made in groups in a face-to-face traditional way.

b) *Transparency and maximization of alternatives*

The importance of transparency in decision-making is that it allows to be seen, by all interested parties, that all the relevant technical, economic and moral issues have been considered. For this, decisions must be based upon the principles of OR—hard and soft. OR and DSS are good controlling mechanisms to ensure that decisions are made in a transparently justifiable way and not on the basis of some capricious whim.

One of the fundamental freedoms in a democratic society is the right of a citizen to know and participate in a decision situation when decisions about valued-concerns are being made that affect the welfare of those people and the places they live in. The Internet is at the core of a change in getting access to information in a timely manner. As scientific decision-making is based on ample information the Internet can help legislators and political consultative bodies to increase the efficiency, effectiveness and transparency of decision-making. Moreover, we can download many DSS software from the Internet.

Internet will increase efficiency and transparency of the government and enable the public to supervise the government better and greater and to gain public access to information, helps to make the government more accountable to citizens. This may lead to the transformation from traditional government to electronic government which is one of the most important public policy issues of our time. Hence, the current status of the Internet in Eritrea has to be upgraded by increasing its bandwidth, so that people get timely information and their participation and interaction with the state be maximized.

According to De Coning and Cloete (2000:27), policy-making exercises require participation and public choice, which involve direct representation, empowerment and active decision-making. If development is defined as the capacity to make rational choices, the participatory nature of policy process is clearly of primary importance. Policy-making processes should incorporate opportunities to exercise choices and explore rational options. These rational options are the results of appropriate interface of human, OR and DSS tools as well. DSS tools like V.I.S.A, enhance transparency as the people affected are able to know of the methods (such as weights) employed.

If the popular participation the government is striving for is not aided by OR approaches, DSS , and communication technology like the Internet, maximization of alternatives will be hampered, as asymmetrical access to information may lead to inferior policy choice.

c) *Restructuring*

In the Eritrean public sector, the awareness being insignificant, the demand for OR and DSS is low. The low demand of users for more progressive OR techniques and DSS also may kill the motivation of system designers to think creatively. A situation of catch-22 may be created in the long run if OR and DSS professionals do not have the chance to exercise and develop their skills on a wider basis. That is, unless these professionals get the chance to exercise and develop their skills today they cannot meet the country's future human resources requirements. Hence, the public sector should be structured in a way that can accommodate both practitioners and professionals in order to complement each others' weaknesses and to rely on scientific decision-making processes.

For the desired change to materialize, there should be institutional restructuring which allows the decision-making process to be inclusive, flexible, multidisciplinary, and governed by a systemic approach. The institutional structures of the government should force synthesis and collaboration not only within one sector, but they should encourage cross-sectoral coordination. Restructuring in such a way as to make public organizations receptive to new approaches to decision-making and the application of OR techniques, is conducive to modernization. The restructuring process should involve the assignment of personnel by merit and the replacement of untrainable personnel by those who can cope with change and technological development. In addition, the restructuring process must include the establishment of an OR team on an organizational level and create an OR society on a national level to lay a foundation for the exchange of experiences and steering operations on a scientific basis. The Government OR team has to be multi-disciplinary, containing not only people with degrees in OR but also graduates from a whole range of numerate analytical backgrounds. The most important shared characteristic is an ability to use their analytical capability to understand and tackle the 'messy' problems of government.

d) Training, and creation of OR and DSS awareness

The government must systematically strive to create OR awareness both within its domain and in the private sector. Efforts should be made to have an OR advocate within the top management and high political circles. Support from these classes of people is important for successful OR practice in organizations.

One way of creating awareness is training. Public officials should get comprehensive training to be able to understand and use decision support tools, facilitate the development of OR specialists, and appreciate the value of OR teams and the synergy they can create. If public officials are well trained and conscious of the need of scientific methods of decision-making, there will be great potential for the application of OR and DSS in their departments and open their minds for further developments that incorporate the OR and DSS professionals in the decision-making process. Decision makers at all levels of government must have training in the basic concepts of mathematical modeling including the interpretation of results.

The good judgment and intuition capabilities that were evolved in the protracted war have to be supplemented by training for the adoption of new technologies and techniques (DSS and OR). Training expedites the acquisition of better decision techniques by the new generation as well. Training for the improvement of the methods of work and laying the foundation for implementation must be one of the top priorities of the government. This can be a positive step towards a peaceful societal transformation that eliminates the discontinuities generated in the long war. Training for OR and DSS creates a common denominator for the older and younger generations that bridges their gap in the decision style. Training and the shift from old work habits may involve cost, but be that as it may, that is the only way to achieve sustainable development, which in the long run is worth the effort. If public servants are properly trained, placed and oriented, society will enjoy the fruits of technological aspects of administration.

e) Centralized database

Different sectors of the government waste time collecting similar data which is a redundant activity resulting in unjustifiable wastage of financial and time resources. There should be a centralized database system in all organs of the state can make use of. A substantial amount of public data collected by different organizations could be consolidated into one central data source. In this way, greater data collection efficiency could be achieved, eliminating the frequent and repetitious data collection efforts of many agencies. Hence, if data are pooled in one data source they will be available for easy access by all government organizations.

Given Eritrea's low financial resources this centralized database is more feasible for the time being until economic development is achieved. However, due to their limitations centralized databases must give way to the more efficient and modern distributed database system. Centralized databases are vulnerable to a single point of failure. Turban, McLean, and Wetherbe (1999:759) argue that when the centralized database computer fails to function properly, all users suffer. Additionally, access speed is often a problem when users are widely dispersed and must do all of their data manipulations from great distances, thereby incurring transmission delays. With better economic status the country has to move towards distributed database system. Turban, McLean, and Wetherbe (1999:759) further state that a distributed database has complete copies of a database, or portions of a database, in more than one location, which is usually close to the user. This alleviates the single point-of-failure problems of a centralized database as well as to increase user access responsiveness.

f) Foster a project approach to implementation

Due to the fact that Eritrea is in the reconstruction stage, many projects are underway in the Eritrean public sector today. Since the start of some projects depends upon the completion of others, it is imperative to identify the activities which are critical and need more attention than others for the smooth completion of the whole project. Activities have to be sequenced, responsibilities assigned to specific individuals, and costs allocated accordingly so that objectives are attained at measured strokes. To develop strategies to fund and schedule such series of projects require the application of dynamic programming, and electronic DSS. As projects are instruments of development, much attention has to be given to their proper management.

Though for the most part the method of carrying projects in Eritrea entailed more art than science we should approach the project management effort systematically and tip the scales in favor of science over art. Projects must be managed according to the principles of project management aided by Microsoft Project software in order to save cost and time and to achieve the desired results. Hasty and shortcut approaches to solve immediate problems may lead to rework and duplication that drains, tax-payers money.

g) Develop systems approach

On a wider basis, not only one ministry, but the public sector as a whole has to be seen as operating in one system. As its name implies, a sector is only a part of the whole, so its activities must be complementary. Though the different sectors have their own objectives, they should have a systems view in which underachievement by one sector negatively affects the objectives of the others. For instance, if the activities of the Ministry of Fisheries affect the environment, the objectives of the Department of Environment will be frustrated. Public sector organizations must not be concerned only of their local optimization but should look for a point for global optimization within the country. If optimization by one sector leads to suboptimization by another sector, the efforts of the former will amount to nothing and its gains be cancelled out by the losses of the other.

h) Development of appropriate policies

There should be policies for every aspect of activities at all levels of the government—at the strategic, tactical, and operational levels—which include policies for appropriate inventory levels (that minimize cost and ensure smooth flow of operations), land use, ecological and environmental sustainability, establishing the optimal level of service stations (e.g. in banks and hospitals), optimal facility locations, and the selection of appropriate decision-making styles and tools. Unless government programs are guided by clear policies there will be inconsistencies in the decisions made, and evaluation and development will be seriously hampered, with long-term repercussions.

Policy communicates a clear direction of where the government is going in a particular area and why. It makes decision-making more consistent, articulates the roles, responsibilities and authorities of various parties and clarifies the principles, values and goals underlying a particular approach. Policy can only be effective if it is informed by relevant and credible evidence, including the expertise and experience of constituents. Policy developed through an appropriate inclusive process ensures that those who have an investment in the system also have a voice. For reliability and transparency the policy making process has to be supported by known models and DSS.

i) Don't rely on heuristics

The liberation struggle was rich in heuristic methods. In the field where electronic support systems and OR techniques were scanty, many problems were solved heuristically. Practical and short-cut applications were developed out of necessity in the critical moments. Eritrean ex-fighters have gained a lot of experience and developed a pragmatic way of solving problems heuristically like in logistics, transportation, and deployment of personnel and weapons, to mention some. In the absence of relevant algorithmic solutions they resorted to heuristics for faster and cheaper solutions.

However, it may not be feasible to replicate these heuristic methods in the changed situation where societal interaction and new international relations have become more complex in independent Eritrea.. A special effort has to be made to incorporate OR academics and practitioners in the daily operations of the government. Government administrators should not be reluctant to abandon traditional ways of doing things. As real world problems require both qualitative and quantitative techniques their methods of solution should not be skewed to the qualitative methods as is usually seen in the public sector. Every problem is unique and the approach taken to solve it should also be unique and relevant that reflects the new situation. Though heuristics have roles in the absence of scientific methods they do not guarantee optimal solutions and the worst of this method is we may not know how far we are from the optimal and we may be wasting resources unjustifiably.

Nowadays where DSS have gone far towards solving complex OR problems, the public sector has to limit its heuristic approaches—trial and error styles have to give way to scientific approaches to decision-making processes. The built-in inertia of the natural tendency of reluctance to change has to be broken and traditional ways of decision-making have to give way to scientific methods with the aid of DSS.

j) Exploit diversity

On the one hand the 30-year war of liberation has produced many practitioners who developed pragmatic approaches to solve problems. On the other hand, though far from sufficient, Eritrea has some educated people who came from Diaspora, those who stayed under the Ethiopian rule, and those who are freshly educated after liberation. These groups have their own strengths and weaknesses to apply OR and DSS with little training. The government has to try to merge these capabilities with diverse backgrounds and lay the foundation for their collaboration and mutual respect of one another. A conducive environment should be created so that all see their experience and potential as complementary. The government should be keen to benefit from its diverse human resources by taking this diversity as an advantage to widen its solution horizon. Social problems are not satisfactorily solved by a single discipline and homogeneous groups. Heterogeneity in the composition of groups and enhancing their interactivity in the decision-making is one of the requirements of a multidisciplinary approach.

Finally, this paradigm shift in the operations of the State, which has been discussed in this paper, is not easily attained where custom, tradition, and inertia are deeply rooted. A breakthrough in work habits and methods requires long-term commitment and political sacrifice, primarily spearheaded by the government. It is not a snapshot achievement but a process that never ends. The adoption of the OR approach and the use of DSS is not a static outcome that we have to be complacent about, but it is a dynamic process that we have to adjust and keep abreast with time for them to be instruments of continuous improved policies.

k) Development of relevant models

Models should not be adopted for the sake of modeling. If models are too general or irrelevant their effect is more harmful than good. Therefore they must be built for the specific purpose they are intended to serve. Models have to be compatible with the Eritrean context and the specific sector and problem. The understanding of the context of the models—that is, the reasons behind the problem, the constraints on its solution and the problems of implementation—is vitally important to the good construction of the model and solution derived from it. In most situations, the best model is the simplest model that accurately reflects the relevant characteristic or essence of the problem being studied. In general, the fundamental characteristics of the problem should guide the selection of an appropriate OR modeling technique.

These modeling techniques do not produce indisputable solutions. Because of their multicriteria structure and the political environment in which it is found, a decision to most public sector problems is always open to debate and second-guessing. There is no one, correct answer. And, because such work is of a public nature, it has to be assumed that the results and the process by which the results were obtained have to be available for review. These considerations must be recognized by the OR analysts and be addressed in a positive and satisfactory manner. This can only be accompanied by clear and understandable documentation of the computer-based model and its use. In addition, decision-makers should be included in the model formulation and development stages. They will be suspicious of the models that are dumped on them if they have not provided input during model-building stages.

Finally it can be stated that public administration has undergone tremendous changes during the past few decades. Pressure has been exerted that public administration should look towards business to observe how to manage its available resources in a more optimal manner. An entire paradigm shift has taken place from the old bureaucratic manner in administering the work of states, and a much more business oriented approach, with OR and DSS, has been introduced. Eritrea is not different and has to follow suit.

l) Future research

This study attempted to show that decisions supported by OR and DSS are more rational and save all types of resources. It explored only the potential of the wide applicability of these techniques in the public sector in general. There is ample opportunity to make a focused case study to meet the specific efficient operational needs of a particular activity in any unit or department. The best ways (more efficient, effective, and sustainable method) of arriving at a rational decision so as to make the best use of our resources through sound governance has to be explored in various aspects. Given its historical background and current level of economic development Eritrea should be more concerned about the productive use of its material, financial, human, time, and knowledge resources. The selection and application of a relevant decision support, OR and electronic support system, for a particular situation are yet to be explored.

Furthermore, as researchers became progressively interested in nonlinear situations where a system exhibits extreme sensitivity to variations in initial conditions, the study of the application of OR and DSS in the complex and uncertain environment of public policy should be viewed and studied in light of chaos theory.

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Annexure

Annexure A

Many researchers and historians agree that groupthink was evident in the Nixon cabinet and was a contributing factor to the Watergate scandal and the resulting resignation of a U.S. president in 1974. The debacle associated with the Iran hostage rescue attempt in 1980 has also been attributed to groupthink. More recently, several researchers have suggested that groupthink was evident in decisions made just prior to the challenger space shuttle disaster in 1986. (Marakas, 1998:159).

Annexure B

COMMERCIAL BANK OF ERITREA

CONFIDENTIAL

Code No:
Category:DTS
Trading License No.:

Loan Approval Form | Branch Liberty Avenue | Date

1. Name of Applicant ....
2. Facility Applied for (Other Requests) ......
3. Purpose of Facility ....
4. Applicant's Business ....

5.Present Facilities	Limits Approved	Present Balance	Expiry Date	Interest Rate P.A.
Overdraft Facility	....	....	....	....
Merchandise Loan at .... % Advance	....	....	....	....
Adv. On Imp.Exp. Bills at........% advance	....	....	....	....
Term Loan at Nakfa .... per month	....	....	....	....
Sub Total	———	———	———	———
Letters of Credit at ....% margin (sight)	....	....	....	....
Letters of Credit at .... (Acceptance)	....	....	....	....
Guarantees Issued by the Bank (Foreign)	....	....	....	....
Guarantees Issued by the Bank (Local)	....	....	....	....
Grand Total	———	———	———	———

6. SECURITY OFFERED DESCRIPTION	EVIDENCED BY	VALUE

7. Turnover of O/D or C/A — This Year Nakfa .... — Last Year Nakfa ....

SWING		SWING	
HIGHEST DEBIT	HIGHEST CREDIT	HIGHEST DEBIT	HIGHEST CREDIT
1/	1/	1/	1/ ....
2/	2/	2/	2/ ....
3/	3/	3/	3/ ....
LOWEST DEBIT	LOWEST CREDIT	LOWEST DEBIT	LOWEST CREDIT
1/	1/	1/	1/ ....
2/	2/	2/	2/ ....
3/	3/	3/	3/ ....

8. Applicant's Net Monthly/Yearly Income .... (ii) Guarantor's Net Monthly/Yearly Income ....
9. Import & Export Figures (Show separately amount authorized & Utilized)

Nakfa .... Nakfa ....

Annexure C

10. OTHER LIABITIES TO THE BANK & THIRD PARTIES (INDICATE IF ANY OVERDUE)

BORROWER	GUARANTOR

11. BREAK DOWN OF THE FINANCIAL STATEMENST OF BOROWER & GUARANTOR			
(Borrower in 000's Nakfa)		(Guarantor in 000's Nakfa)	
Particulars: Year ____	Year ____	This Year	Last Year
Net Working Capital NAKFA	NAKFA	NAKFA	NAKFA ....
Capital & Reserve		....	
Profit/ Loss		....	

12, 13 **General Remarks:**

14. **Recommendation** Or **Decision** of **Branch Manager** (Give reasons for Declining)

15. **DECISION OF LOANS COMMITTEE** (Give reasons for declining or for deviation for the Recommendation)

16. **DECISION OF CENTRAL OFFICE OR MANAGEMENT CREDIT COMMITTEE** (Give Reasons for Declining or for deviation from the Recommendation)

Annexure D

14/07/03

MINISTRY OF LAND, WATER AND ENVIRONMENT
LAND DEPARTMENT

REPORT

MAP of ALLOCATION PLAN and PARCEL BASED DATABASE of ADI-KE

MAP INDEX - A-2440V

Index