DETERMINATION OF AN EFFECTIVE RESOURCE ALLOCATION STRATEGY BASED ON FACTORS INFLUENCING RISK WITH DIFFERENT COMPUTERISED SYSTEMS

by

Hendrik Abraham Krüger, M.Comm

Thesis submitted in fulfilment of the
requirements for the degree PHILOSOPHIAE DOCTOR
in COMPUTER SCIENCE AND INFORMATION SYSTEMS
in the faculty of ECONOMIC AND MANAGEMENT SCIENCES at the
POTCHEFSTROOMSE UNIVERSITEIT VIR CHRISTELIKE HOËR ONDERWYS

Promoter	**:**	**Prof. J M Hattingh, D.Sc**
Co-promoter	**:**	**Prof. P J S Bruwer, D.Sc**

November 1993

ACKNOWLEDGEMENTS

I will ***"trust in the Lord with all my heart and lean not upon my own understanding"***

(Prov. 3:5).

I am deeply grateful to my CREATOR without whose strength and wisdom this work would not have been possible.

I hereby wish to express my sincere appreciation to the following persons and institutions for their guidance and motivation :

- My promoter, Prof J M Hattingh, for his professional guidance and assistance;
- My co-promoter, Prof P J S Bruwer, for his valuable comments and assistance during the study;
- Anglo American Corporation of SA, Gold Internal Audit for leave granted as well as initial financial support to enable me to start the study;
- Prof A L Combrink for editing grammar and style;
- Mrs G H Visser for a professional typing job which she so often selflessly carried out;
- My parents for their moral support and encouragement throughout the duration of this research project.

This work is dedicated to my parents whose inspiration for excellence in education goes beyond words.

CONTENTS

PAGE

CHAPTER 1

PROBLEM STATEMENT

CHAPTER 2

PLANNING FOR MIS RESOURCES

PAGE

CHAPTER 3

ISSUES CONCERNING MIS RESOURCES

PAGE

CHAPTER 4

RESEARCH ENVIRONMENT, RESEARCH METHOD, STATISTICAL AND OTHER TECHNIQUES USED

PAGE

CHAPTER 5

PROCESSING AND ANALYSIS OF DATA

PAGE

CHAPTER 6

OPTIMISATION TECHNIQUES APPLIED TO THE LINEAR REGRESSION MODELS

PAGE

CHAPTER 7

ALLOCATION OF RESOURCES

CHAPTER 8

SUMMARY, CONCLUSION AND RECOMMENDATIONS

PAGE

CHAPTER 1

PROBLEM STATEMENT

1.1 INTRODUCTION

The importance of developing an Information Technology Resource Plan is stated as follows by *Robert E Umbaugh* [88]:

> *Information Technology Resource Planning should be a high-priority task for the IS Management Team. Despite the appearance of dwindling IS budgets for computer hardware - as indicated by lower per-unit hardware costs, increasingly higher networking costs, and a higher proportion of direct costs allocated to systems development - the truth is that organisations' dependence on information technology is increasing in almost every case. It is more important than ever that a thorough job be done in planning for this vital resource.*
>
> *Forecasting demand and planning for needed IS resources is, however, an increasingly complex job.*

Literature studies [40], [88] have indicated that computer resource planning generally constitutes the provision made for equipment, software, personnel and facilities.

Umbaugh [88] summarises these needs into four categories for which resource planning is necessary.

(a) Contingency - resource planning to prepare for the unexpected. Such resources may be seen in physical terms, e.g. Direct Access Storage Devices (DASD), or stated as a percentage or range of percentages, e.g. Central Processing Unit (CPU) capacity will be the projected load plus 18%.

(b) Availability - resources which will enable a system to satisfy demands placed on it by users.

(c) Reliability - resources necessary to ensure an acceptable level of uptime of any individual component of a system (including software).

(d) Demand - demand-driven systems (e.g. online, time-sharing, text retrieval and office systems) usually peak during prime time shifts. Identifying and projecting demand and controlling peak loads as well as scheduling IS [1] resources are primary tasks in IS resource management.

Although different tools and techniques exist to manage these resource needs, the allocation of financial resources to computer systems, based on the systems' importance to the organisation, as well as the risk and success of the system, are not widely discussed or available in the literature.

[1] See endnote

The Standards for the Professional Practice of Internal Auditing [39] quoted the following as part of the scope of the function of the internal audit:

> *Economical and Efficient use of Resources - Internal Auditors should appraise the economy and efficiency with which resources are employed.*

The purpose of this quote is twofold. Firstly, the reader should be fully aware of the fact that the research was conducted from an internal auditing point of view, as the writer is employed as a Computer Auditor by a major company. Secondly, the appraisal of resources is not merely a function performed by Internal Audit Departments but could be seen as a direct order issued by the Institute of Internal Auditors. Naturally this includes all resources necessary to run a business satisfactorily. Therefore, resources employed in a computer environment are also subject to appraisal by Internal Auditors. This in turn implies that a scientific, tested and reliable method be found which will assist Managers in the important task of allocating financial resources to different computer systems.

1.2 OBJECTIVE OF THE STUDY

The study was initiated due to the required existence of a reliable resource allocation strategy for management, as well as the need for a tool that can be used by Internal Auditors to appraise the allocation of resources to different computerised systems.

Specific objectives can be summarised as follows:

(i) To determine which factors contribute most to
- the risk of a computerised system
- the success of a computerised system

(ii) To prioritise computerised systems according to their perceived importance.

(iii) To determine, through the use of optimisation techniques, which the major factors are which should be changed to maximise the success and minimise the risk of the computerised systems.

(iv) To formulate a model which will enable management to allocate resources to different computerised systems optimally, based on the importance, risk and success of each computerised system. This model should also be usable as a tool for Internal Auditors to appraise the allocation of resources.

Objectives number (i), (ii) and (iii) above are necessary to make the formulation of a resource allocation model meaningful. By identifying factors, as well as indicating which ones are the major role players, the allocation in practice would be simplified. Should these first three objectives be omitted, it would lessen the impact of the study to a great extent. Management would have no indication on where to spend their resources, except that they would know that resources should be allocated to minimise risk or maximise success.

It is important that readers of this study keep in mind that the research was conducted at **one** specific organisation using different computerised systems. Factors, prioritising of systems and data used in developed models are specific to this one organisation. However, the techniques and models developed could be used in any organisation.

Various contributions have already been made by other researchers in identifying and establishing relationships among risk and success factors. Research on the prioritising of different systems has also been completed. These contributions will be referenced and elaborated on in other chapters. The combination of these issues with the aim of developing a model to allocate resources to computerised systems does, however, need further investigation and research.

1.3 DIVISION OF CHAPTERS

As MIS resources are central to this study it is necessary to provide enough theory on the issue. Chapter 2 will look at the planning and managing of MIS resources in general as it is described in available literature on this subject. The planning and managing of the resources will also be discussed from an audit point of view.

Important research and existing knowledge in respect of success and risk factors as well as prioritising of systems and allocation of resources will be discussed in Chapter 3.

In Chapter 4 the research method, research environment and techniques used will be discussed and in Chapter 5 the data obtained are analysed and investigated using different statistical and other methods. Chapter 6 describes the optimisation techniques applied to the linear regression models while a model to allocate resources to different computerised systems based on all data obtained and processed will be developed in Chapter 7. A general summary, conclusions and recommendations form the contents of Chapter 8.

The appendices contain questionnaires, factors used in the study and data obtained regarding these factors.

1.4 PROBLEMS DURING THE STUDY

The most important problem encountered was obtaining input when it was required from users of the different systems. The nature, scope and physical site where the system was used made it impossible to involve the "right user". This problem was solved by making use of "main users". This term refers to a senior person who has been in service of the company for a considerable number of years. These employees have a good knowledge of the majority of computerised systems and were, or still are, involved as users in the majority of the systems.

Another minor problem was to get honest, dedicated answers from all personnel involved. The research project was not regarded as a high priority by personnel from whom input was needed. Answers could therefore have been given just to finish the questionnaire. This problem was mostly overcome through personal interviews where questions and the importance of the project were explained, while one respondent at a time completed the questionnaire.

To conclude, results of this research project should provide guidelines to management when dealing with the ever-increasing importance of aspects regarding the allocation of resources to various computer-based systems. Internal auditors should equally be interested in the results as it will provide them with a technique to appraise the allocation of resources or to act as consultants whenever such allocations have to be made.

ENDNOTE:

Throughout this thesis, depending on the context, the following acronyms were used:

MIS - Management Information Systems
IS - Information Systems
IT - Information Technology
EDP - Electronic Data Processing
DP - Data Processing

CHAPTER 2

PLANNING FOR MIS RESOURCES

2.1 INTRODUCTION

In his discussion on strategic and long-range planning *James* [43] stated the following:

> *Long-range planning for MIS traditionally has focused on the prioritisation of application development or acquisition projects. Necessary as this focus is, it misses the mark by failing to assess the impact of strategic considerations, such as changes in the organisation's business, in its culture, or in technology.*

With the ever-increasing importance of information technology and bigger investments made in the technology field, it became necessary for each organisation to ensure that they have adequate strategic and long-range plans available to take advantage of the strategic potential offered by computer-based systems.

This chapter will briefly review the planning function and challenges that await management. A summarised information technology resource plan, as discussed in the literature, will be presented and finally a brief discussion on control and audit issues relating to computing resources will be given.

2.2 PLANNING

The planning process is defined in several ways in the literature. The following two examples provide an adequate description of the concept:

> *The basic objective of planning, however, is to provide a basis for today's actions and decisions that ensures that the organisation's resources are effectively and efficiently acquired and used in support of its mission. Planning is also the rational management of change.* [43]

Duffy and Assad [29] describe planning as:

> *Planning is deciding in advance what has to be done. It bridges the gap from where we are to where we want to go. Managers plan for the allocation of resources and the work of other people, in contrast to the non-manager, who plans only his or her own activities.*

According to *James* [43] planning is a cyclic process, producing actions that cause results and learning from the results. This process is illustrated in Figure 2.1:

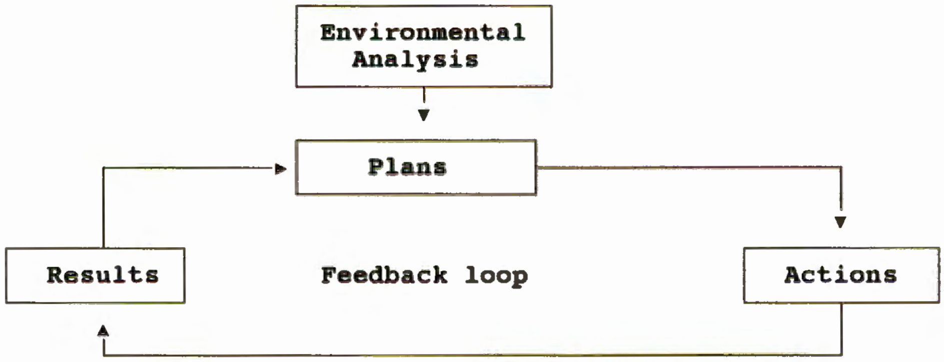


Figure 2.1 The Planning Process [43]

In his explanation of the planning process James indicated that planning may be categorised and characterised in the following three ways: [43]

- Planning classified by functions

  - Strategic planning is concerned with an organisation's mission and how it changes in response to the organisation and its environment. This function is usually performed by top-level management. [77]

  - Tactical planning involves ensuring that action plans can be carried out. It includes identifying milestones and estimating resources required for completing tasks. A one- or two-year budget plan for a specific project is an example of tactical planning. This phase of the planning process is conducted by middle management. [77]

  - Operational planning is the planning of the daily work required to carry out the action plans. The production schedule of a data centre may be an example of operational planning which is usually conducted by low level managers. [77]

  Figure 2.2 illustrates these concepts as seen by *Head* [36]:

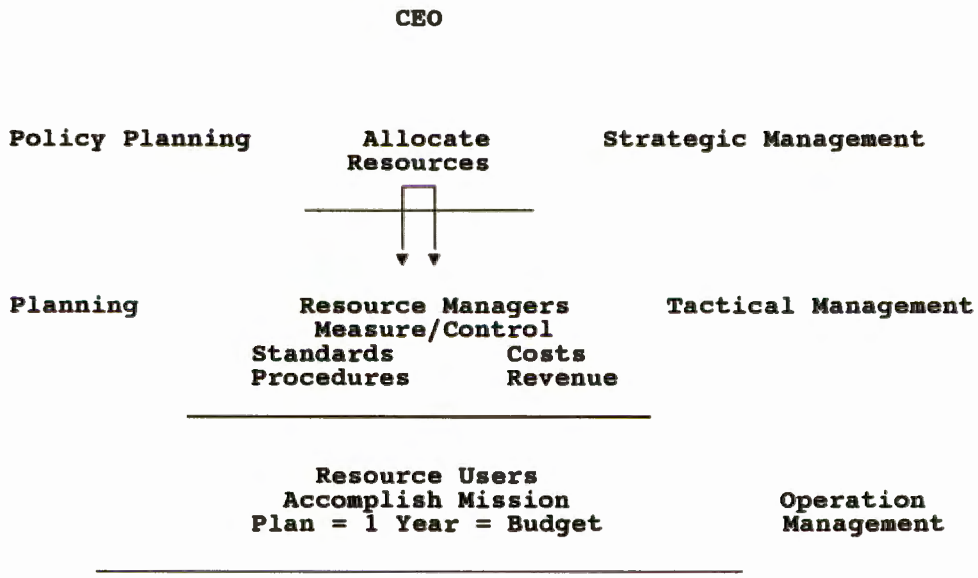


Figure 2.2 Strategic Planning Framework [36]

- Planning characterised by its time-frame

  - Long-range planning usually involves looking at least five years ahead.
  - Short-range planning involves all forms of planning for the immediate future and includes most operational planning, one- or two-year financial plans, etc.

- Planning categorised with respect to what is planned. If, for example, an information resource plan has to be drawn up, the following elements should be addressed:

  - Information systems requirements
  - Resources needed to meet those requirements such as human, physical, financial and information resources
  - Organisational plans for deploying and controlling the resources

Whichever way the planning process is classified, the fact remains that it is something which should be done and the purpose of it can be summarised as: [29]

- Minimising the effects of unexpected changes
- Maintaining the stability of the organisation
- Enabling it to react efficiently and effectively to future situations
- Providing a mechanism for control

Finally, with regards to an IS plan specifically, when all IS strategy activities are formulated, it will culminate in a complete IS plan which may be either a long- or a short-range plan, depending on the nature of the organisation.

The purpose of such a specific IS plan is summarised by *Duffy and Assad* [29] as intended to:

- couple IS development to the overall corporate plan;
- give direction to IS development and to ensure that this development supports the objectives of the organisation;
- record the resource allocation and priorities of IS development;
- ensure the integration and co-ordination of IS development to avoid 'islands of mechanisation', sub-optimisation and unnecessary costs of integration at a later stage;
- provide a yardstick against which the performance of the managers responsible for IS development can be measured, i.e. to enable control to take place;
- provide a basis for the acquisition and development of scarce IS personnel, such as business analysts and system analysts;

- ensure the continued adaptability and support of the organisation by its Information Systems; and
- gain a sustainable competitive advantage from information technology.

2.3 INFORMATION TECHNOLOGY CHALLENGES FOR THE NINETIES

The information technology field is changing continually, which implies that management styles, needs and planning have to be adapted as circumstances, technology and IT investments change.

Dixon and Darwin [23] discussed issues facing corporate management in the 1990s and concluded that new paradigms for managing the deployment of technology are required. IT Manager's principal tasks in the 1990s will have to be much more those of a senior executive. A list of fourteen principal tasks are listed by them which include, among others, and relevant to this study, to "*Juggle contradictory and scarce resources*".

In his work on managing information technology in the nineties, *Selig* [81] argued that a good business plan can only be developed and executed through the partnership between the business unit managers and the managers of the financial, personnel and IT resource units. According to him there are 5 main challenges facing management:

- The organisational challenge
- The resource allocation challenge
- The operational challenge
- The technology challenge
- The partnership challenge

In the changing environment, the increasing strategic potential of information systems is well accepted. *Miller and Pitt* [60] listed *'Using information systems for competitive advantage'* as the second most important issue as perceived by a group of South African information systems managers. Research on factors affecting strategic information systems applications has been conducted by *King and Sabherwal* [50] and may be seen as an indication of efforts to improve and maintain a competitive advantage gained through the use of systems with strategic potential.

One of the problems emanating from systems with strategic potential, and already identified during the late 80s by *Lederer and Mendelow* [54], is to convince top management of the strategic potential of such systems. Table 2.1 lists six reasons, identified by them, for top management's reluctance to recognise the strategic impact of Information Systems while Table 2.2 offers a list of techniques to overcome this reluctance.

Table 2.1

REASONS FOR RELUCTANCE TO RECOGNISE STRATEGIC IMPACT	
1.	Top management lacks awareness
2.	Top management sees strictly operational use of computers
3.	Top management perceives a credibility gap
4.	Top management does not view information as a resource
5.	Top management demands financial justification
6.	Top management is action-oriented

Table 2.2

TECHNIQUES TO OVERCOME RELUCTANCE	
1.	Educate top management
2.	Market accomplishments of Information System Department to top management
3.	Have user do the selling
4.	Promote business image for the Information Systems Department
5.	Respond to outside forces
6.	Capitalise on changes in management
7.	Perform Information Systems Department planning

2.4 AN INFORMATION TECHNOLOGY RESOURCE PLAN

According to *Umbaugh* [88], resource planning is of vital importance and he stated that:

> *Far too many IS installations operate without a comprehensive resource plan. If an installation is to prosper, the IS manager should begin now to improve resource planning.*

Computer resource planning generally constitutes the provision made for equipment software, personnel and facilities. *Umbaugh* [88] suggests using the CARD approach (Chapter 1) when planning for hardware requirements. This approach makes provision for evaluating and planning for Contingency, Availability, Reliability and Demand.

Subsequently there is a brief discussion of aspects to be considered when an information technology resource plan has to be compiled. The paragraph then concludes with an outline for a computer resource plan. The discussion and outline of the plan are quoted from *Umbaugh's* [88] discussion where detailed information on the developing of an information technology resource plan is available.

A resource planning methodology, designed to meet the needs of an IS installation, should consider the following:

- Load duration analysis and planning

  An analysis of the processing load imposed on a data centre gives a processing profile for that data centre. The following are methods which may be used to conduct these analyses:

  - Time zones

    A processing day may be divided into different time zones with workload categories superimposed on them. This can help avoid the trap of relying on average daily load figures. It will also enable management to identify the source and size of peak loads.

  - Capacity corridors

    A capacity corridor is established by taking the difference between optimal capacity of a device and a reasonable estimate of practical capacity. Whenever projection of workload reaches or enters the capacity corridor, the work load is processed at risk and some form of response is needed. The response must be determined before it is actually necessary to take action.

- Reserve margin

  To achieve reasonable levels of reliability, some fallback computing capacity, or reserve margin, is needed. To establish and justify reserve margins, load duration curves, which represent the demand expected on every working day in a year, are designed. The reserve margin is then calculated using the extent to which the peak hour within a day exceeds the average hourly traffic during the entire working day.

\- Peak-load management

Several steps can be taken to address the peak-load problem, of which the following are some of the more easily implemented techniques:

- Time-of-day pricing

  A simple, yet effective, policy to follow is to differentiate between rates charged during peak-load times and other times

- Conservation

  This is simply to request employees to avoid using computing resources they do not need

- Load-shifting

  Load-shifting is the temporary use of outside resources to delay the acquisition of more own resources

- Peak-sharing

  The idea with peak-sharing is to identify those elements that make up the peak load and then reduce them. Examples of such methods include restricting the use of high-resource-using but low-priority applications during peak hours and the implementing of flexible work hours to lower the peak load.

- Projecting future needs

  Projecting future need is a critical part of the planning process and is perhaps the most difficult estimation in planning for IS resources. Obtaining reliable forecasts of resource requirements has always been a demanding task and resource planners should use all techniques and information available. Helpful steps in obtaining this information may be the use or drawing-up of system descriptions, schedule of events and resource requirements for each specific system.

The completion of all the above steps and investigations should culminate in a technology resource plan as outlined in Table 2.3. This outline is a guide to developing a resource plan and should be adapted to the needs of an organisation. The plan should be kept current and reviewed regularly.

Table 2.3 Outline for a Computer Resource Plan [88]

1	Executive Summary a) Basic description of IS activities and purpose of plan b) General assumptions regarding IS environment c) Financial impact of plan, cost per year and cash-flow requirements d) Major hardware and software summary
2	Strategy a) Milestone events b) Planned activities
3	Project Analysis a) Summary of each major system
4	Demand System Impact a) Text processing b) Graphics c) Open shop use d) CAD/CAM e) Electronic mail
5	Equipment Plans a) CPU, memory and channels b) DASD c) Tape drives d) Communications devices e) Satellite processors
6	Software Analysis (operating system) a) Installed software categories (e.g. operating system, communications software, database management software and programmer productivity aids) b) Forecast software requirements for period of plan c) Major software events (event chart) d) Software configuration chart
7	Data Communications Network a) Network configuration b) Network events (event chart)
8	Personnel Plan a) General staffing requirements b) Training requirements c) Recruiting requirements d) Project staffing charts
9	Facilities a) Building modifications required b) Space requirements for projects c) Facility event chart
10	Other a) Word-processing evaluation b) Future expert systems impact c) Decision support requirements d) Executive information system support

2.5 RISK, CONTROL AND AUDIT CONSIDERATIONS RELATING TO COMPUTING RESOURCES

> *The internal auditor's review of the activities associated with managing computer resources is critical to verifying that a controlled environment exists. The security, integrity and reliability of this environment contribute to the reliability and integrity of the applications and the data processed therein.* [40]

The ever-changing and substantial advances in information technology necessitate the involvement of auditors in reviewing an organisation's information technology resource plan. To do this effectively, auditors need to have a framework which they can use when auditing this important function. *The Systems Auditability and Control manuals, module 4 - Managing Computer Resources* [40], was written with the aim to provide internal auditors with such a framework.

A brief summary of the issues concerned, as described in [40], is given below.

Factors that influence risks, controls and audit considerations with regard to the management of computer resources in a larger information systems function include:

- The organisation of the function
  The IS function may be organised into different structures (centralised, departmental, personal computing) but the following three issues apply to all structures:

- Span of control - One of the risks may be too few managers who have to supervise a great number of employees, thus raising the risk of inadequate supervision.

- Segregation of duties - When duties cannot be adequately segregated, there is an increased risk of errors and irregularities.

- Training - Rapid changes in technology make training critical for new and existing staff.

- Computer resource management

  This involves maintaining facilities, maintenance and providing support services. Risk and control considerations usually include reviewing areas such as system failures and physical security.

- Operating environment

  Each type of organisational structure supports different operating environments, each with its own considerations. The more general considerations to take into account are traditional batch-orientated or database/data communications orientated data centre, time-sharing, networks and information centres which will include issues such as change control procedures, poorly structured applications and incomplete data in databases.

- Service relationships with a service bureau or facilities manager

  Some of the obvious risks in this area are unstable vendors, operational problems at the servicer, loss of data during processing or transmission, modification of programs by the servicer's staff and unauthorised access to confidential data.

- Systems software and systems programming activities
  Examples of issues with which management should be concerned include system security and integrity, system performance, system continuity and reliability, system recovery and hardware expandability.

2.6 SUMMARY

Chapter 2 gave a brief overview of planning concepts as a management function, possible information technology challenges facing corporate management and also quotes from the literature a framework which may be used when drawing up a computer resource plan. A discussion of the risk, control and audit considerations relating to computing resources concluded the chapter.

CHAPTER 3

ISSUES CONCERNING MIS RESOURCES

3.1 INTRODUCTION

In his work on planning for an Internal Audit function, *Boritz* [4] stated that:

> *To be effective, the resource allocation process must be firmly based upon the approved objectives set for the internal audit department. It should specify a set of appropriate assumptions consistent with those of corporate management.*

This quote is equally important to the resource allocation process pertaining to MIS resources. It would be acceptable to assume that the assumptions made by both Internal Audit and MIS management are based on pre-defined and evaluated risk and success factors as well as perceived importance of computer-based systems.

The objective of Chapter 3 is to give an introduction to these issues facing management. Risk, success and importance aspects relating to computer-based systems, and described in the literature, will be discussed. The discussion is then concluded with an example of a model used to allocate audit resources in an organisation, and developed through research conducted by the Institute of Internal Auditors.

3.2 RISK

3.2.1 Introduction

> *Risk. We internal auditors use the word frequently. We seem fascinated, almost obsessed, by it. We assess and we evaluate risk. We talk about risk factors and categories. We say that risk influences what we audit and when we audit.*

This quote from the work of *Anthony P Walz* [94] clearly indicates that risk is a key concept in internal auditing. It appears that this key concept is equally appropriate when dealing with computer-based systems. The Statement on Internal Auditing Standards - Number 9 [41] recommends, as a first step during the risk assessment process, that auditable activities must be identified. Among others, these activities include:

> *... Information systems (manual and computerised) ... Functions such as electronic data processing, ...*

Support for this idea of risk as a key concept in computer-based systems can be deduced from literature which deals with computer security, system and applications controls, etc. [26], [64], [67], [92].

The importance of risk and risk assessment stemmed from the challenges confronting management to maximise effectiveness with limited resources. To meet this challenge thorough planning is necessary and the planning process should be based on careful assessment of the key risks facing and influencing the organisation and its systems. In addition, from an audit point of view, these risk assessments should culminate in developing a prioritised audit work schedule.

One of the most significant guidelines to follow in a risk assessment exercise is perhaps the Statement on Internal Auditing Standards - Number 9, Risk Assessment [41] which was mentioned earlier. Other literature which demonstrates the importance of this issue is the comprehensive 12-Module Systems Audit and Control manuals [40] issued by the Institute of Internal Auditors. The institute is constantly engaged in research to improve existing or develop new tools and techniques to assist in this important function. The Toolkit-Risk assessment [45], also developed by the Institute, is an automated method which auditors may use to assess an area's risk by evaluating and weighting pre-defined risk factors.

A comprehensive list of literature (19 different research projects or investigations) relevant to risk assessment and methods for scheduling audit work can be found in [89]. The most significant work, on which certain parts of this research project are based, is the work carried out by *Patton, Evans and Lewis* [66]. They presented a model for allocating constrained audit resources across multiple audit areas within a single period. To achieve this, they made use of pair-wise comparisons, ranking of audit areas and allocating resources accordingly.

3.2.2 Statement on Internal Auditing Standards No 9 (SIAS No 9) [41]

The statement, simply called 'Risk Assessment', was issued in December 1991 by the Institute of Internal Auditors and it describes the elements of the risk assessment process for use by an internal auditing department.

Every organisation has its own special needs and surely there are different ways to approach the task of risk assessment. For this reason SIAS No 9 only provides a conceptual framework for understanding the process.

The definition of risk, as used in SIAS No 9, is the probability that an event or action may adversely affect an organisation. Possible effects of risk are listed as follows:

- An erroneous decision emanating from using incorrect, untimely, incomplete or otherwise unreliable information.

- Erroneous record-keeping, inappropriate accounting, fraudulent financial reporting, financial loss and exposure.

- Failure to adequately safeguard assets.

- Customer dissatisfaction, negative publicity and damage to the organisation's reputation.

- Failure to adhere to organisational policies, plans and procedures, or not complying with relevant laws and regulations.

- Acquiring resources uneconomically or using them inefficiently or ineffectively.

- Failure to accomplish established objectives and goals for operations or programs.

It is clear from this list (which is not exhaustive) that the potential adverse effects of risk for an organisation can be widespread.

The risk assessment process itself involves three phases to be completed, viz.:

- Identification of auditable activities;
- identification of risk factors; and
- assessment of the significance of risk factors.

The first phase is to identify and catalogue all auditable activities where an auditable activity consists of those subjects, units or systems which are capable of being defined and evaluated. A list of examples, which includes computerised information systems, is given in the Statement.

The second phase in the process involves the identification of risk factors relevant to the auditable activities. These risk factors are, according to the Statement, the criteria used to identify the relative significance of, and likelihood that, conditions and/or events may occur that could adversely affect the organisation. Another important remark in the Statement is that the number of risk factors should be limited, but sufficient to provide confidence that the risk assessment will be comprehensive. The Statement again supplements these definitions with a list of fourteen possible risk factors.

The third and final step involves the organising and integrating of professional judgements as a basis for developing an audit work schedule. Management should now incorporate information from all possible sources to arrive at the mentioned judgements. In his discussion of SIAS No 9, *Urbanic* [89] states:

> *Assessing the significance of the risk factors necessitates judgements regarding the probability of adverse events. In making these judgements the internal auditor may find it helpful to assign*

> *each factor with a numerical weight to represent its potential impact on selecting an activity for audit.*

Finally, SIAS No 9 noted that the risk assessment process should be conducted regularly to assess the effect of any major changes in the catalogue of auditable activities or related risk factors.

3.2.3 Computer security risk management

According to *Palmer and Potter* [64],

> *'Security' implies the protection of a system against all kinds of mishaps or misuse.*

They explained that on all computer systems the threats and risks fall into five categories, viz.:

- Destruction of assets;
- unauthorised modification or manipulation of information assets;
- unauthorised disclosure of information assets;
- denial of use of an asset; and
- fraud.

They further argue that the only way to protect computer systems is by using proven risk management techniques and provided the following structure (Figure 3.1) to explain the process of analysing risk:

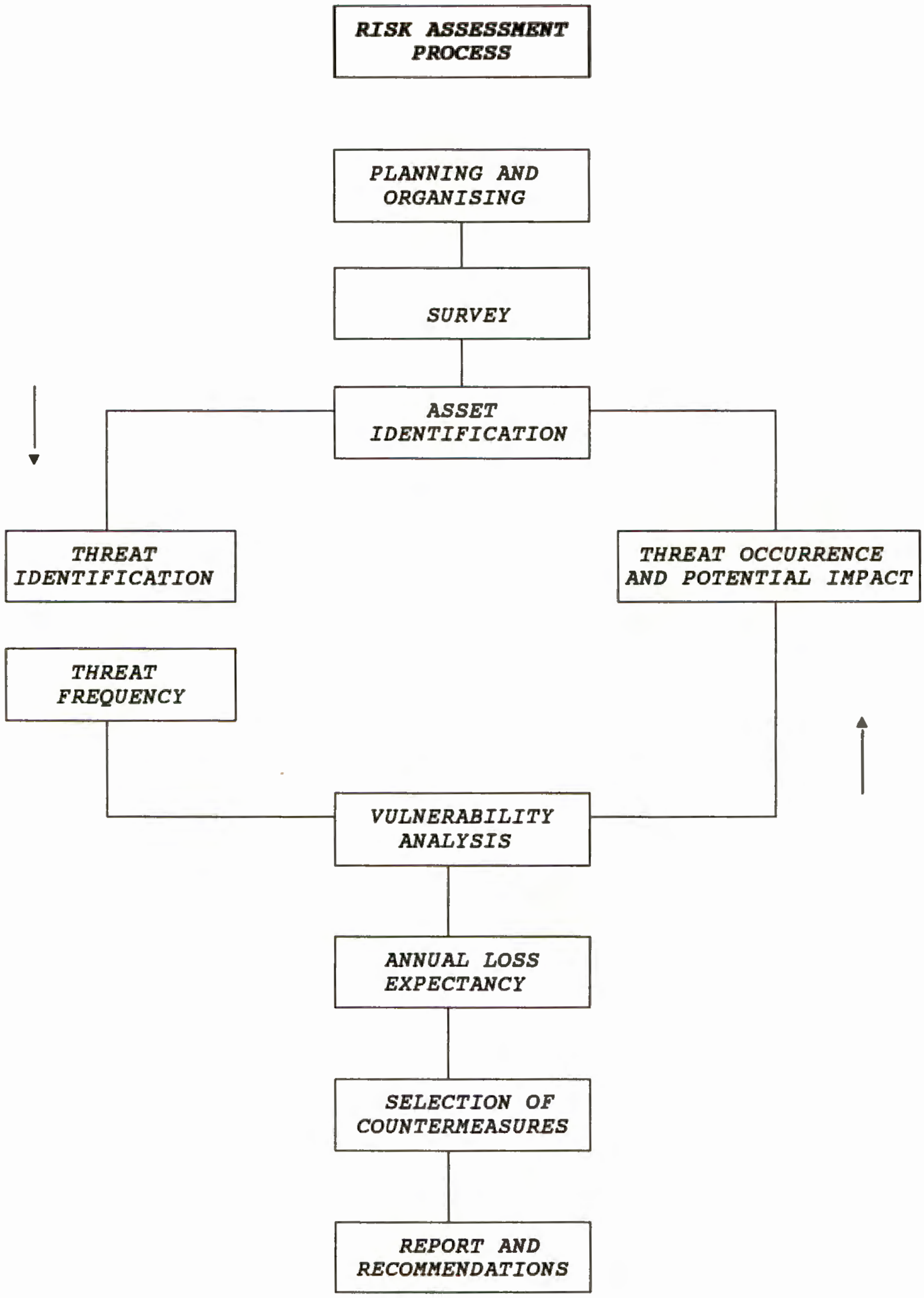


Figure 3.1 Process of Risk Analysis [64]

It is easy to see from Figure 3.1 that most of the basic tasks of a risk analysis process can be described as the identification of factors influencing risk and the measurement (quantifying) of these factors. In identifying threats, their frequency of occurrence and potential impact, as well as conducting a vulnerability analysis, it would be necessary to identify relevant factors influencing these different aspects.

The second important task that can be seen from Figure 3.1, before any countermeasures can be considered, is the calculation of an annual loss expectancy. This is an effort to measure and quantify the impact of threats in terms that management can readily understand and accept.

According to *Palmer and Potter* this calculation, which was originally described by *R Courtney*, has two components:

- **The likelihood of the occurrence of the risk**

  This is estimated in orders of magnitude, ranging from once in 300 years (magnitude 1) to once in 30 years (magnitude 2) and so on to once per 15 minutes (magnitude 8).

- **The magnitude of the monetary impact of each occurrence**

  This is estimated from \$ 10 (magnitude 1) to \$ 100 (magnitude 2) and so on to \$ 10 million (magnitude 7).

If *f* is the magnitude assigned to likelihood of occurrence and *i* is the magnitude assigned to the monetary impact then the following formula is suggested to be used to determine the annual loss expectancy (ALE):

$$ALE = \frac{10^{(f+i-3)}}{3}$$

If, for example, a specified risk is likely to occur once in three years then f = 3. If the cost impact is of the order of $ 100 000 per occurrence, then i=5. This produces an annual loss expectancy figure of about $ 33 000. The following table has been constructed and is in use to inter-relate the values of impact (i) and frequency (f):

Impact (i)	Frequency (f)							
	1	2	3	4	5	6	7	8
1	*	*	*	*	300	3k	30k	300k
2	*	*	*	300	3k	30k	300k	3m
3	*	*	300	3k	30k	300k	3m	30m
4	*	300	3k	30k	300k	3m	30m	300m
5	300	3k	30k	300k	3m	30m	300m	*
6	3k	30k	300k	3m	30m	300m	*	*
7	30k	300k	3m	30m	300m	*	*	*

Any combination of impact and frequency ratings which falls within the area marked with asterisks indicates either a calculation error or a major problem which demands immediate correction before proceeding with the risk assessment.

Support for this technique can be found in other literature too [26], [67].

The process described in the previous paragraphs may and should be incorporated in a business' broad disaster recovery or contingency planning which is summarised by *Palmer and Potter* as in Figure 3.2.

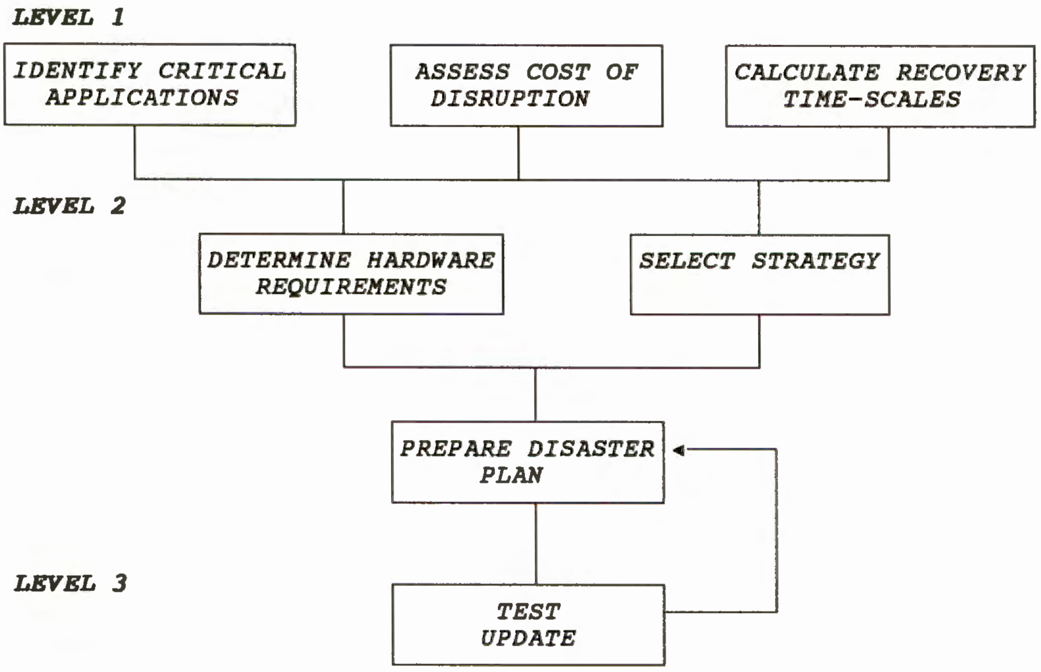


Figure 3.2 Disaster Recovery Process [64]

3.3 SUCCESS

3.3.1 Introduction

The constant desire of managers to improve the productivity and effectiveness of information systems has motivated the ongoing research and development of tools to measure and analyse these issues.

In their research, *Bailey and Pearson* [1] have quoted other researchers, and this has indicated that:

> *.... productivity in computer services means both efficiently supplied and effectively utilised data processing outputs. Further, it is argued that utilisation is directly connected to the user community's sense of satisfaction with those services.*

In the past various factors or other variables which may influence the success of a computer-based system have been investigated. Apart from investigating factors and their relationships, true efforts were also made to develop measurement tools and techniques to enable management to improve their management capabilities such as planning.

Bruwer [5] has listed some of the earlier researchers who studied the success of information systems, and in his own research make use of a restricted linear regression model to evaluate factors which were identified with the help of regression and correlation analysis. Other contributions in this and related areas of *Bruwer* could be found in the literature [8], [9], [10], [11], [13], [14].

The literature contains a number of attempts to identify factors influencing success as well as attempts to measure user satisfaction.

Miller and Doyle [55] designed an instrument for measuring effectiveness of information systems and came to the conclusion that the better performers were those firms where the level of performance matched the perceived importance of the particular aspect of IS. An instrument to capture the perceptions of end-users has been developed by *Miller and Ross* [58] in order to measure and achieve success in an End User Computing environment. This was preceded by research conducted by *Ross* [71] into the effectiveness of end user computing. Other attempts to measure user satisfaction and issues related to that may be found in [21], [25], [42], [85]. The most notable, perhaps, is *Bailey and Pearson* [1].

As far as the identification of success factors is concerned, examples of relevant research may be found in [22], [24], [62], [82], [93]. Comprehensive lists of other researchers can also be found in the work carried out by *Miller* [57] and *Emanuel* [30]. *Udo and Davis* [91] investigated the relationship of selected predictor variables with the tangible and intangible benefits of decision support systems in the financial services industry. They concluded that benefits (success) are affected by four groups of factors, viz. industry, organisation, system and user attributes. *Stanley* [83] also conducted research in the financial sector to study those factors which would make an information system project a success in terms of a company's strategy.

Key factors to successfully manage the development of strategic applications are described by *Krcmar and Lucas* [52] while lists of success factors can be found in [1], [16], [72] and [97].

3.3.2 Definitions

It is clear from the introduction that to measure the success of a computer-based system one needs to measure and analyse user satisfaction or as *Miller and Doyle* [55] put it:

> *... to measure 'user information satisfaction' as a surrogate for the overall effectiveness of information systems in the organisation.*

It may therefore be accepted that a successful system is a system which is in accordance with the perception of users, effective and efficient. This in turn implies user satisfaction.

The terms effective and efficient are described as follows by *Scudder and Kucic* [80]:

> ***Efficiency*** *is concerned with the resources consumed in producing a given application in a timely manner.*
>
> ***Effectiveness****, on the other hand, is concerned with the quality of the finished product and its appropriateness to the problem/ situation for which it was designed.*

The definition introduced by *Bailey and Pearson* [1] for user satisfaction is accepted in this study and is as follows:

> *... satisfaction is the sum of one's positive and negative reactions to a set of factors. An individual's feeling must, in this model, be placed somewhere between a 'most negative' reaction and a 'most positive' reaction.*

This model is described as:

$$S_i = \sum_{j=1}^{u} R_{ij} W_{ij}$$

where

R_{ij} - The reaction to factor j by individual i

W_{ij} - The importance of factor j to individual i

The reader must note that, although specific importance ratings for factors were not carried out during the fieldwork for this research project, it can be assumed that respondents intuitively weighted each factor as they completed the questionnaires. Identification of most important factors was facilitated by regression and correlation analysis.

3.3.3 Factors affecting the success of computer-based systems

From these introductory notes it is clear that to implement a model which attempts to measure or analyse user satisfaction it is necessary to adhere to two different requirements, stated by *Bailey and Pearson* [1] as:

> *First, the set of factors comprising the domain of satisfaction must be identified. Second, a vehicle for scaling an individual's reaction to those factors must be found.*

As already indicated in the introduction, many research projects have been completed to address both the above-mentioned requirements. Tools and techniques used in this research project relied heavily on the same principles applied by *Bruwer* [5] as well as making use of the factors identified by *Bailey and Pearson* [1]. For completeness' sake and to further clarify the needed requirements, a very brief discussion of their work would be appropriate.

Research conducted by *Bruwer* [5]

It should be noted that the research conducted by Bruwer was based on principles and techniques introduced by *Henry C Lucas Jr* as explained in [5]. Bruwer's study should therefore be seen as building and expanding on certain of the original work carried out by Lucas.

The objectives of Bruwer's study can be summarised in the four following points:

- To investigate the use of computer-based information systems and their success as perceived by the user.

- To determine which factors make the largest contribution to the success of computerised systems.

- To determine, by means of optimising methods, which factors are the most important to change, so that the performance of the information systems may be optimally improved.

- To formulate a model which would enable the management of an organisation to apply capital in such a way that the computerised systems may provide optimum performance.

Bruwer has identified, from the literature, a list of factors which are likely to have an impact on the success of computerised systems. These factors were then used in a descriptive model (Figure 3.3) and with the aid of questionnaires were evaluated on a 7-point scale by both users and management in a very large organisation.

With the aid of BMDP statistical programs, correlation and regression methods, linear relationship between certain variables and success were investigated. A linear regression model was then obtained consisting of twelve independent variables which explained the changes in success.

To study the interdependence of decision variables and to prevent unrealistic proposals a restricted model was utilised. Finally, a general cost model, which attempts to give guidelines on how funds should be applied to optimise the success levels, was proposed.

The advantage of this project was that a procedure was developed which could be useful for the management of an organisation of which the performance of computer-based systems is poor.

Research conducted by *Bailey and Pearson* [1]

Bailey and Pearson initially identified 36 distinct factors from the literature which are likely to affect computer user satisfaction. Through revisions, interviews and other tests a final list of factors, comprising 39 different factors, was drawn up and used in their research.

The measurement technique proposed was based on the use of adjectives to describe the characteristics of concepts and objects. Bailey and Pearson found their motivation in psychology and argued that:

> *Since people use adjectives to explain their perception of things, adjectives can be used to measure those perceptions.*

Measurement was accomplished by rating four bipolar adjective pairs for each factor on a seven-interval scale.

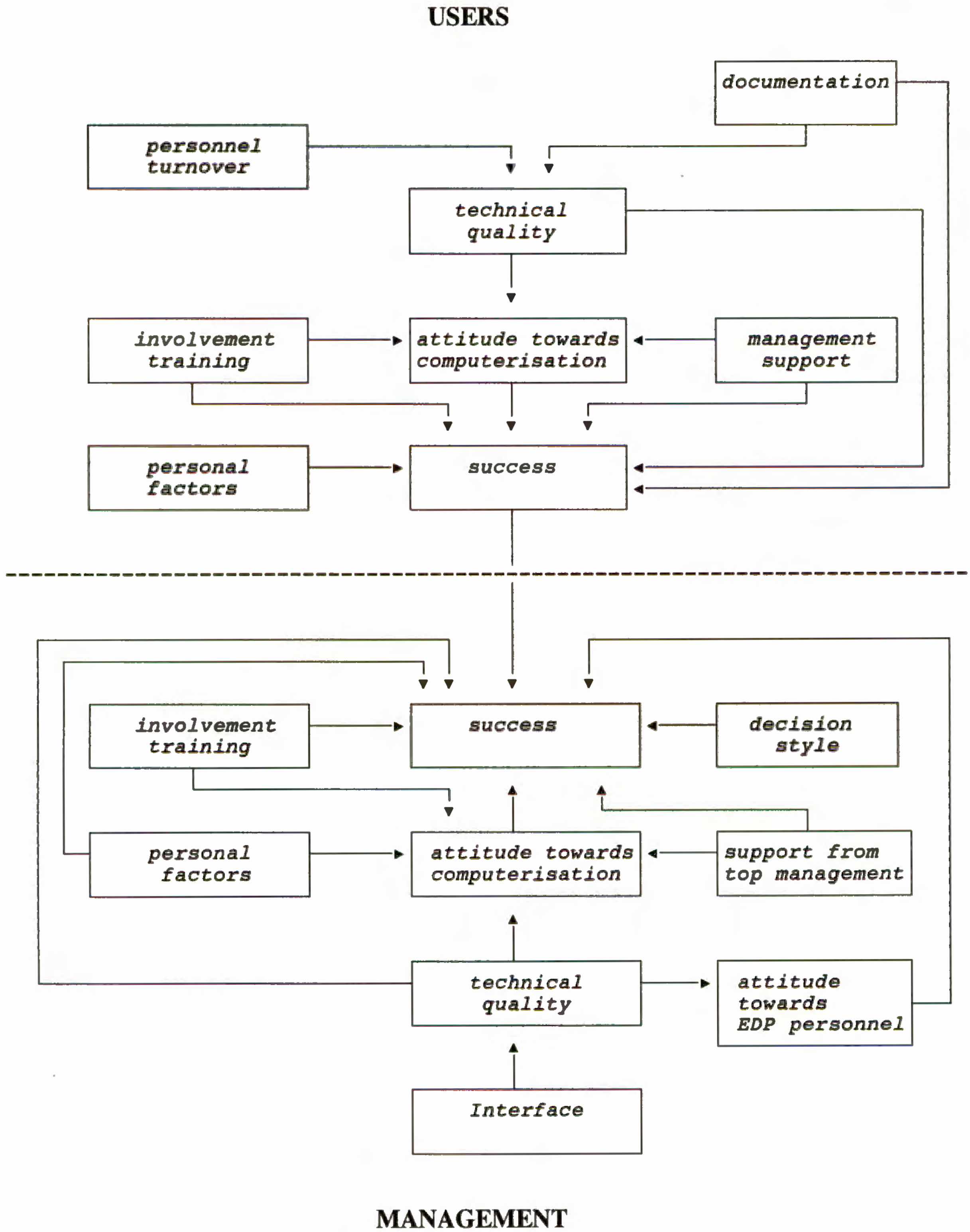


Figure 3.3 Descriptive model used by Bruwer [5]

Figure 3.4 illustrates these principles:

Degree of EDP training provided to users:

The amount of specialised instruction and practice that is afforded to the user to increase the user's proficiency in utilising the computer capability that is available.

complete	incomplete
sufficient	insufficient
high	low
superior	inferior
satisfactory	unsatisfactory
to me, this factor is important	unimportant

Figure 3.4 Illustration of Questionnaire Form [1]

Two additional scales were added to assess the satisfaction and importance levels which were necessary for the user satisfaction definition as well as for testing the validity of the instrument. To avoid deceiving measurements the score on questionnaires was normalised to $\pm$ 1,00.

The 39 factors, their definitions and adjective pairs are attached to this study as Appendix G.

The development of this instrument has led to the appearance of a number of other instruments and revised versions of this specific instrument as detailed by *Miller* [57]. There was also criticism that the instrument is out of date [25].

It was decided for this study to accept the 39 factors, as identified by Bailey and Pearson, as sufficient. This decision was based on:

- The fact that various forms of literature exist on success factors and the measurement of user satisfaction. This indicates that it would be unnecessary to start a new study project to identify relevant factors.

- The research carried out by Bailey and Pearson was tested by them for reliability, content, predictive and construct validity. *Miller and Doyle* [55] quoted other researchers who convincingly argue for the adoption of Bailey and Pearson's techniques.

To keep models as simple as possible the 39 factors were divided into eight main factors. Each main factor comprises certain sub-factors chosen from the list of 39 sub-factors.

The eight factors with their accompanying sub-factors were:

	FACTOR	SUB FACTORS FROM BAILEY
F_1	Top management involvement	a) Top management involvement
F_2	EDP staff/user relationship	a) Relationship with the EDP Staff b) Communication with EDP Staff
F_3	EDP staff quality	a) Technical competence of the EDP Staff b) Attitude of the EDP Staff
F_4	EDP centre/function	a) Schedule of products and services b) Means of input/output with EDP centre c) Charge-back method of payment or services d) Organisational position of the EDP function
F_5	System output characteristics	a) Accuracy b) Timeliness c) Precision d) Reliability e) Currency f) Completeness g) Format of output h) Volume of output
F_6	Effect of system on users	a) Organisational competition with EDP unit b) Feeling of control c) Degree of training d) Job effects e) Feeling of participation
F_7	Issues concerning conventional system characteristics	a) Flexibility of systems b) Integration of systems c) Convenience of access d) Language e) Relevancy f) Error recovery g) Security of data h) Documentation i) Expectations j) Understanding of systems k) Perceived utility l) Confidence in the systems m) Response/turnaround time
F_8	Quality of service from EDP staff/centre	a) Priorities determination b) Time required for new development c) Processing of change requests d) Vendor support

Miller and Doyle [55] have indicated that their seven factors map well onto critical success factors identified by other researchers. The eight main factors, derived from *Bailey and Pearson* and used during this research project, map equally well onto *Miller and Doyle's* seven factors:

```
Factor                                                       Miller and Doyle

F1 - Top management involvement  -----------------------▶   Strategic management

F2 - EDP staff/user relationship -----------------------▶   User involvement

F3 - EDP staff quality           -----------------------▶   IS staff quality

F4 - EDP centre/function         -----------------------▶   Responsiveness to
                                 -----------.               new system needs
                                            :
F5 - System output characteristics -----.   :
                                        :   :
F6 - Effect of system on users   -----:-----:-----------▶   End user computing
                                      :     :
F7 - Issues concerning conven-   -----:-----:-----------▶   Characteristics of
     tional system characteristics    :-----:-----------▶   conventional systems
                                            :
F8 - Quality of service from EDP -----------:-----------▶   Reliability of
     staff/centre                           :-----------▶   systems
```

3.4 IMPORTANCE OF SYSTEMS

3.4.1 Introduction

Much has been written on planning as one of management's functions. *Miller and Pitt* [60], in their research on priorities in information systems, listed the top ten issues with *Improving IS Strategic Planning* as the most important key issue facing South African information system managers. To fulfil this task of strategic planning, managers have to identify and prioritise their different information systems in order to make meaningful decisions, such as the allocation of resources.

From an audit point of view it is also necessary to be able to prioritise information systems, as this information is needed for audit plans, working schedules and allocation of audit resources.

3.4.2 Examples of research

Many examples of research to address the problem of prioritisation can be found in the literature. Some of these examples will be referenced in this paragraph.

Klein and Beck [51] presented a method to aid in multiple attribute decisions involving descriptive, qualitative attributes. It is a step-by-step approach where the decision-maker, at certain steps, is asked to state his preference for one alternative from a set of two alternatives.

A partial-ordering framework for ranking Information Systems is described by *Lay* [53] as a methodology to rank an organisation's portfolio of systems according to the real needs of the organisation.

The procedure is as follows:

- The portfolio is checked for completeness.

- A hierarchy of attributes pertinent to the organisation is established and weights are assigned to each attribute using the Analytic Hierarchy Process (developed by *T L Saaty* [76]).

- The systems in the portfolio are then scored against sets of attributes by three groups of participants.

- The responses of the participants are analysed for consistency and consensus using Spearman Rank Correlation and/or Correspondence Analysis.

- The portfolio is then divided into two sets: a strategic component and a support component. Each component is then analysed in terms of contribution and risk.

- The sub-sets of the portfolio are then grouped into priority categories based on measures of concordance and discordance using a technique known as *ELECTRE II.*

A technique described by *Drummond* [28] and called the function points technique, is used to measure applications and their performance. This technique could be used for ranking systems according to specific functions and attributes, as indexes may indicate which systems are important to consider when, for example additional resources have to be allocated to unproductive applications. The technique specifically identifies the following features of an application: External inputs, external outputs, external enquiries, complexity of masterfiles and system-to-system interfaces. Once these information-providing elements have been individually classified, the overall application is considered. The impact of various innovation and technology factors such as transaction volume, real-time updating, communications or multisite installation is assessed. The sum of these factors that influence a project is then applied as a percentage against the sub-total of the previously counted deliverables to arrive at the function points index for the application.

Other techniques, used by researchers for other purposes, may also be used for ranking systems. Examples of such techniques may include statistical methods (regression) and operational research techniques (linear programming) as used by *Bruwer* [12] to rank information systems problems in a User Environment. *Scudder and Kucic* [80] also describe a possible method, which they use for measuring performance, called budgetary performance measure. In this technique the cost of a project is related to its benefits and a return on investment is computed.

3.4.3 A simple auditor's ranking model

A simple and easy-to-use method was developed by *J Fitzgerald* [32] specifically for use by internal auditors. A software tool called RANK-IT was also developed to assist in the ranking process. Although the technique was developed with the aim of conducting risk ranking exercises, it may be used to rank or prioritise any list of criteria.

A brief summary of the methodology as described by *Fitzgerald* [31] is as follows:

- It is a quick and inexpensive method which quantifies and automates the ranking process by combining the Delphi technique with comparison ranking. This ranking is an ordinal ranking.

- **Ordinal ranking**: Ordinal lists express order or succession in a series. It is the sequencing of systems or other judgement criteria into a series that is ranked from high to low. For example, in an ordinally ranked list the top item is perceived to be the most important (risky, sensitive, costly, etc.) the next item down is perceived to be the second-most important, and so forth.

- **Delphi technique**: This technique entails the selection of a few experts who have in-depth knowledge about the systems being reviewed. This group of people will give their opinions on the systems in order to reach a final decision.

- **Comparison ranking**: Comparison ranking is combined with the Delphi methodology to obtain consensus. For example, assume that different systems have to be ranked. The Delphi team is selected first. It then meets to discuss issues affecting the system. After discussing these issues, the Delphi team members combine their opinions to form a consensus as to which system might be the most important one to the organisation. The process used to arrive at this consensus is called Comparison Ranking.

A comparison ranking sheet (Figure 3.5) is used to record the member's opinions. The opinions are formed and recorded by casting a vote when comparing the relevant judgement criteria for each system against each of the other systems. The Delphi team members do not have to quantify, for example, specific losses because their votes are based on their experience and knowledgeable perceptions. Their concern is about, which is more important or of equal importance, not an exact value. These votes are then added together. It is summed down each column (upper right half of cell). The totals are then combined for each summation (down and across). This results in a final ranked list (Figure 3.6) which is an ordinally ranked list of systems with the most important item at the top.

SYSTEM 1	SYSTEM 1					
SYSTEM 2	1 4	SYSTEM 2				
SYSTEM 3	0,5 4,5	4 1	SYSTEM 3			
SYSTEM 4	1,5 3,5	3 2	2,5 2,5	SYSTEM 4		
SYSTEM 5	0 5	4 1	4 1	4 1	SYSTEM 5	
SYSTEM 6	0 5	3 2	0 5	1 4	1 4	SYSTEM 6

Figure 3.5 Comparison Ranking of Systems [31]

ITEM	VOTE TOTAL
SYSTEM 6	20,0
SYSTEM 2	18,0
SYSTEM 4	13,0
SYSTEM 3	12,0
SYSTEM 5	9,0
SYSTEM 1	3,0

Figure 3.6 Final ranked list of systems [31]

There are a number of advantages for internal auditors using this easy method, viz.:

- The ranking can be completed in a timespan that can range from as little as a few minutes to a few hours, depending on the size and complexity of the decision criteria being ranked.

- The technique greatly simplifies the consolidation of opinions because it allows each system to be compared with each other system once and only once. It also allows two systems to be compared while totally ignoring all other systems. This is a great benefit in human decision-making.

- Key decision-makers accept the final results because they are active participants in the decision-making process.

3.4.4 The analytic hierarchy process

The analytic hierarchy process as developed by *Saaty* [76] is a framework which may be used to describe elements of a decision problem as well as a procedure for scaling and linking these elements.

The approach, described in more detail in Chapter 4, consists of three steps. The first step is to structure attributes into a hierarchy such as shown in Figure 3.7.

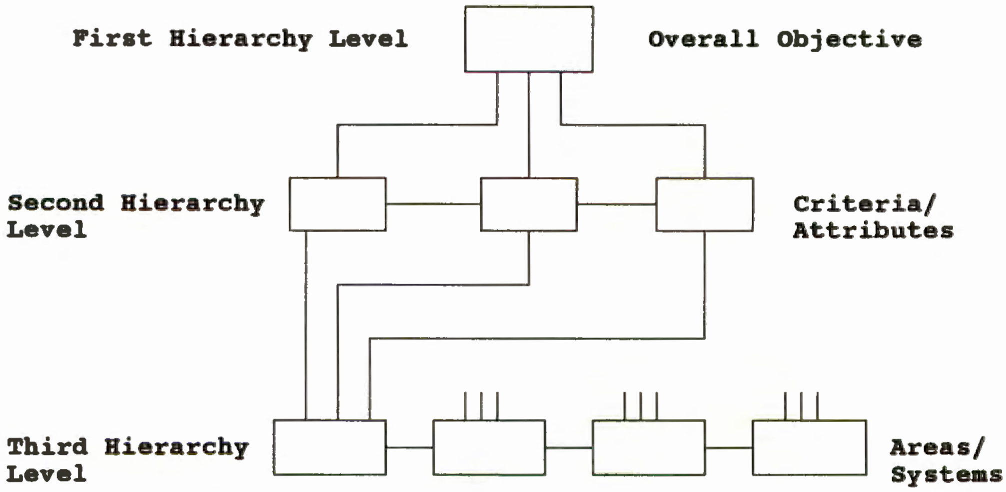


Figure 3.7 Hierarchy for Priorities of Systems

In the second step each pair of attributes is evaluated with respect to the next higher attribute in the hierarchy. These evaluations, which are recorded in a matrix, are carried out using a pre-defined scale from 1 to 9 (Chapter 4).

The final step involves the calculating of resultant weights using an algorithm involving eigenvectors and eigenvalues.

Although *Saaty's* techniques may be criticised in certain areas, the validity of the approach has been demonstrated in several cases. The application of the technique by *Patton et al.* [66] is perhaps the most significant with regard to internal auditing. The technique remains a scientific method for analysing attributes in order to prioritise certain elements and may still be applied with confidence.

Formal advantages of hierarchies according to *Saaty* [73] are:

- They provide meaningful integrations of systems. The integrated behaviour or function of a hierarchical organisation accounts for the fact that complicated changes in a large system can result in a single component.

- Hierarchies use aggregates of elements in the form of levels to accomplish tasks.

- Greater detail occurs down the hierarchy levels; greater depth in understanding its purpose occurs up the hierarchy levels.

- Hierarchies are efficient and will evolve in natural systems much more rapidly than non-hierarchical systems having the same number of elements.

- Hierarchies are reliable and flexible. Local perturbation does not perturb the entire hierarchy. The overall purpose of the hierarchy is divided among the levels whereby each solves a partial problem and the totality meets the overall purpose.

3.5 ALLOCATION OF RESOURCES

3.5.1 Introduction

As already indicated, and described in Chapter 2, computer resource planning generally constitutes the provision made for equipment, software, personnel and facilities. This paragraph will concentrate on the allocating of audit resources. Such allocations are usually based on risk and perceived importance of systems/audit areas and this therefore closely relates to the central research problem of this study. The study is also aimed at internal auditors (Chapter 1) and allocation of audit resources should be brought into perspective.

A lot of research on the allocation and scheduling of audit work has been carried out in the past [3], [89]. The framework developed by *Patton et al.* [66] is an authoritative research project and is often mentioned in other researchers' work [4], [46]. Parts of the work were applied in this research project and it therefore warrants further clarification.

3.5.2 The *Patton, Evans and Lewis* framework [66]

The objective of internal auditors is to allocate their internal audit resources to minimise loss. A firm's loss function in each audit unit may be stated as the sum of audit-risk factors (*f*) multiplied by importance weights (*w*). The resulting sum is then multiplied by $1/a_i$ to reflect that the total loss in an audit unit is reduced as the level of internal auditing (resources) increases. (a_i = internal audit resources allocated to audit unit *i*).

The total loss for a firm then simply is the sum of the losses in each audit unit and may be mathematically stated as:

$$\sum_i R = 1/a_1\,(w_1f_{11} + w_2f_{21} + \ldots + w_nf_{n1}) + 1/a_2\,(w_1f_{12} + w_2f_{22} + \ldots + w_nf_{n2}) + \ldots + 1/a_k\,(w_1f_{1k} + w_2f_{2k} + \ldots + w_nf_{nk})$$

where f_{xy} = the value or extent of audit-risk factor x in audit unit y;
w_x = the weight of importance of audit-risk factor x; and
a_y = percentage of total internal audit resources allocated to audit unit y.

The internal audit manager's task is to determine how to allocate the available audit resources among the audit units; that is, what percentage ($a_1, a_2, \ldots, a_k$) of all audit resources should be assigned to each unit?

The problem of allocating a fixed internal audit budget can be solved mathematically as a constrained minimisation problem.

The formal mathematical problem is:

Minimise

$$1/a_1\ (w_1f_{11} + w_2f_{21} + \ldots + w_nf_{n1}) + \ldots + 1/a_k\ (w_1f_{1k} + w_2f_{2k} + \ldots + w_nf_{nk})$$

Subject to:

$$a_1 + a_2 + \ldots + a_k \leq 100\%$$

The audit budget constraint may also be formulated as $a_1+a_2+\ldots+a_k = 100\%$ as the intention is to allocate **all** resources among the various audit units.

The objective is to find (among all possible combinations of percentages [$a_1, a_2, \ldots, a_k$] which satisfy the internal audit budget constraint) the one combination which yields the least loss to the firm. The internal audit budget constraint means that no solution may allocate more than 100% of audit resources.

The problem is solved by first deriving the k+1 simultaneous equations which must be satisfied by the optimal allocation of audit resources. The first k equations result from taking a partial derivative with respect to each of the k-decision variables (a_1, a_2, ..., a_k). For example, the first equation results from taking the partial derivative with respect to a_1.

This yields:

$$\partial R/\partial a_1 = -1/a_1^2 (w_1 f_{11} + w_2 f_{21} + \dots + w_n f_{n1}) + \mu = 0$$

The second equation results from taking the partial derivative with respect to a_2. This yields:

$$\partial R/\partial a_2 = -1/a_2^2 (w_1 f_{12} + w_2 f_{22} + \dots + w_n f_{n2}) + \mu = 0$$

This procedure is repeated for each of the k variables (a_1, a_2, ... a_k), producing a total of k equations.

The last of the k+1 simultaneous equations which must be satisfied in order to achieve the optimal allocation of audit resources is:

$$\partial/\partial\mu = a_1 + a_2 + \dots + a_k = 1{,}00$$

This final equation indicates that the internal audit budget is fixed. Including it ensures that the solution will not violate the budget constraint.

The preceding procedure yields k+1 simultaneous equations which can be solved algebraically for the percentages a_1, a_2, ..., a_k which minimise the total loss of the firm related to internal audit risk.

Using the framework (example and figures quoted from *Patton et al.* [66])

Suppose the analytical hierarchy approach (paragraph 3.4.4) is used to provide for allocating audit resources to four different audit units within a firm. Steps to be followed are:

Step 1 - Risk factor selection

The first step in the process requires audit management to decide which risk factors to include in the model. Assume that five factors were chosen. The full analytical hierarchy of this problem is shown in Figure 3.8.

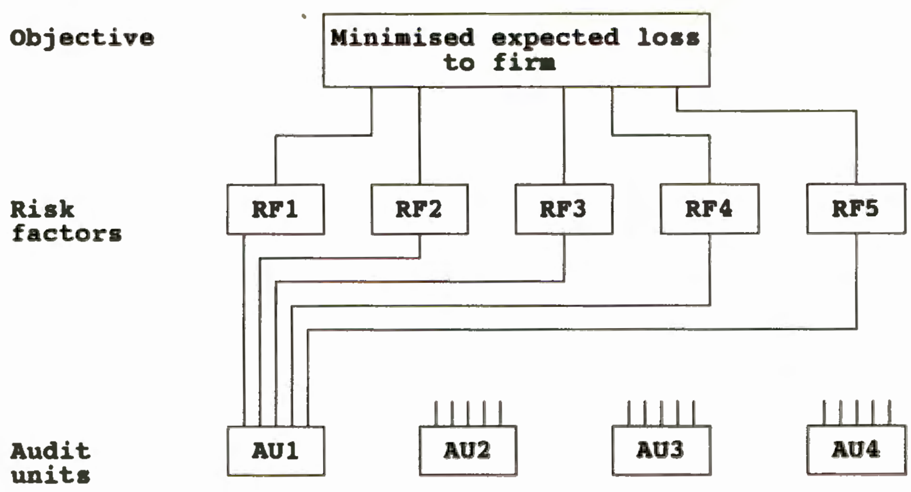


Figure 3.8

Step 2 - Risk factor - importance scale

The second step is to obtain management's perceptions concerning the relative importance of each of the risk factors.

Assume that this process, using the scale-value definitions of *Saaty* [75], results in the following comparison matrix:

	RF1	RF2	RF3	RF4	RF5	EIGENVECTOR
RF1	1	5	3	2	7	0,4475
RF2	1/5	1	1/2	1/3	2	0,0897
RF3	1/3	2	1	1/2	3	0,1540
RF4	1/2	3	2	1	4	0,2534
RF5	1/7	1/2	1/3	1/4	1	0,0554
						1,0000

The importance-scale values, shown in the right-hand column, are the ones most consistent with management's pair-wise judgements.

Step 3 - Audit-unit-risk scales

Next, the relative risk of each audit unit with respect to each of the risk factors must be obtained. Since five risk factors were selected, five separate risk matrices must be constructed. For each risk factor, each audit unit is compared to all other audit units. In this way, the relative extent of each risk factor in each audit unit is estimated.

Suppose that the following scale values (eigenvectors) for each risk factor in respect of each audit unit were calculated:

AUDIT UNIT	RF1	RF2	RF3	RF4	RF5
1	0,5735	0,1150	0,5186	0,1601	0,1095
2	0,2334	0,2124	0,1428	0,2772	0,2576
3	0,1287	0,0708	0,2856	0,0954	0,0692
4	0,0644	0,6018	0,0530	0,4673	0,5637

Step 4 - The composition rule

All scaled elements have to be combined to arrive at the overall unit-risk evaluation. The overall audit-unit-risk evaluation is a weighted average of the audit unit's riskiness on each risk factor, thus:

$$\textit{Overall risk of division } i = \sum_{j=1}^{n} \begin{bmatrix} \textit{Risk of division } i \\ \textit{on factor } j \end{bmatrix} \times \begin{bmatrix} \textit{Importance} \\ \textit{of factor } j \end{bmatrix}$$

This yields:

AUDIT UNIT	OVERALL RISK
1	0,3935
2	0,2300
3	0,1359
4	0,2406
	1,0000

According to this table, the composition rule attributes nearly 40% of the total firm's risk to audit unit 1, as compared to 14% for audit unit 3.

Step 5 - Applying the audit-resource-allocation model

The percentages of audit resources to be allocated to each division can now be calculated.

The k+1 simultaneous equations, in this example, are:

$$-1a_1^2 (w_1f_{11} + w_2f_{21} + w_3f_{31} + w_4f_{41} + w_5f_{51}) + \mu = 0$$
$$-1/a_2^2 (w_1f_{12} + w_2f_{22} + w_3f_{32} + w_4f_{42} + w_5f_{52}) + \mu = 0$$
$$-1/a_3^2 (w_1f_{13} + w_2f_{23} + w_3f_{33} + w_4f_{43} + w_5f_{53}) + \mu = 0$$
$$-1/a_4^2 (w_1f_{14} + w_2f_{24} + w_3f_{34} + w_4f_{44} + w_5f_{54}) + \mu = 0$$

$$a_1 + a_2 + a_3 + a_4 = 1{,}00$$

The first four equations can be simplified by substituting the overall risk, calculated in step 4, for the weighted sums of the risk factors. Using those values, the equations become:

$$-1/a_1^2 (0{,}3935) + \mu = 0$$
$$-1/a_2^2 (0{,}2300) + \mu = 0$$
$$-1/a_3^2 (0{,}1359) + \mu = 0$$
$$-1/a_4^2 (0{,}2406) + \mu = 0$$
$$a_1 + a_2 + a_3 + a_4 = 1{,}00$$

Use the first four equations to express each audit variable in terms of μ. For example, from the first equation:

$$0{,}3935 = a_1^2\mu$$

$$a_1 = \sqrt{0{,}3935/\mu}$$

Do this for a_1, a_2, a_3 and a_4 and substitute in the last equation and solve for μ to get $\mu = 3{,}8653$. Next, use this value in each equation to get:

$a_1 = 0{,}319$

$a_2 = 0{,}244$

$a_3 = 0{,}187$

$a_4 = 0{,}250$

This means that the solution is to allocate total audit resources approximately:

32% to audit unit 1
24% to audit unit 2
19% to audit unit 3
25% to audit unit 4
100%

3.6 SUMMARY

Important research and existing knowledge in respect of risk and success factors as well as the prioritising of systems and allocation of resources were discussed in this chapter. Special attentions was given to these aspects from an internal audit point of view as indicated by the discussions of the statement on Internal Auditing Standards No 9 regarding risk assessment as well as the overview on a possible auditor's ranking model. A comprehensive description, supported by an example of a framework for auditors to evaluate risk and allocate resources accordingly, concluded Chapter 3.

CHAPTER 4

RESEARCH ENVIRONMENT, RESEARCH METHOD, STATISTICAL AND OTHER TECHNIQUES USED

4.1 INTRODUCTION

In this chapter the research environment, research method and different statistical and other techniques used are discussed. These other techniques include optimisation problems, where linear programming is used to optimise given linear regression equations, as well as methods used for prioritising systems.

4.2 RESEARCH ENVIRONMENT

The research was carried out at one specific organisation where the writer is employed in the Internal Audit Department as a computer auditor.

The organisation is a major company in South Africa with diversified interests both locally and abroad. It consists of different divisions and the division within which this Internal Audit Department operates consists of four separate regions. The following combined general statistics (as at 31 December 1991) serve to provide some insight as to the magnitude of the division:

Working revenue	±	R 8 200 m
Working costs	±	R 6 500 m
Capital expenditure	±	R 1 050 m
Distributable earnings	±	R 520 m
Employees	±	182 000

Each of the four regions in the division has its own Executive Management team which reports to one Divisional Managing Director at a Head Office. He in turn reports to a Chairman who is the highest authority within the division.

The four regions are largely self-sufficient with regard to management, administration, personnel, security, production, engineering, health, communication and other general services infrastructure and systems. Due to economy of scale considerations, certain specialist services are provided to the regions via independent service organisations which operate on a divisional basis. These services include:

- Computer Technology and Services
- Research and Development
- Exploration
- Taxation
- Internal Auditing

These service organisations or departments all have their own identity and management. Their managers report directly to a Director at Head Office.

From the above list of service departments, two of them, namely Computer Services and Internal Auditing, are the specific ones where the research was conducted and who may benefit from the results of this study.

4.2.1 The Internal Audit Department

This department was established with the purpose of assisting all managers throughout the Division. Presently it consists of five teams or sections with a total complement of 39 people. One of these sections is the Computer Section where the computer auditors are housed. The Computer Section's work is mainly divisional in nature and in-house driven. This section, with a complement of seven, is also expected to provide the other audit teams with IT support as and when requested.

The department's scope and objectives can be summarised as follows and are intended, i.e., to ensure:

- reliability and integrity of management information produced via the various organisational systems;
- compliance with policies, plans, procedures, laws and regulations;
- safeguarding of assets;
- economical, effective and efficient use of resources; and
- accomplishment of established organisational objectives and goals for operations or programs.

4.2.2 Computer Services

A central Computer Centre was established with the purpose of providing in all divisional IT needs. This includes **all** issues relating to Information Technology.

The centre has an annual budget of ± R 73 m with a complement of ± 273 people who in certain instances are regarded as leaders in specific fields. Examples of such fields are Electronic Data Interchange (EDI) and Electronic Funds Transfer (EFT).

Contracting work for outside organisations is also undertaken.

A portfolio of systems developed and maintained by the Systems Department indicates that there are approximately 158 systems in operation. These systems are divided in main categories such as:

- Technical Systems
- PC Systems
- Finance and Materials Systems
- Engineering Systems
- Hospital Systems
- Payroll Systems
- Human Resources Information Systems
- Time and Access Systems

The portfolio also shows that there are some 87 systems that are not currently in use.

Apart from this "official" list of systems there are also a considerable number of systems that are developed in-house by the regions using their own resources, with only the support (if needed) from the central Computer Centre.

In order to exclude very small and relatively unimportant systems, only 36 systems, currently under development or completed but still maintained, and from time to time enhanced, were chosen for the research project. An additional factor that contributed to the decision to choose 36 systems was the geographical distribution of the systems. Although divisional systems could be evaluated at any site, specific systems posed problems, such as time, cost and availability of users. These 36 chosen systems were used to evaluate and the data obtained were used for developing the models and to draw conclusions as described in further chapters.

4.3 RESEARCH METHOD

The research method used consisted of two basic components, viz. a literature study and practical work, where information obtained during the literature study was applied.

4.3.1 The literature study

Applicable literature was scrutinised in order to get the necessary background and theory on issues such as the management of MIS resources, factors influencing success, risk and importance of computerised systems and the allocation of MIS resources. Results of the literature study were documented comprehensively in Chapters 2 and 3.

Apart from gaining background, the more important reason for the literature study was to obtain information which could be used in drawing up questionnaires, processing and interpretation of obtained data and to develop and test new models.

4.3.2 Practical work carried out

Once the literature study was completed, questionnaires with which the needed data could be obtained were drawn up. In addition, informal discussions were held with experienced EDP personnel, users of computerised systems and computer auditors. Where necessary their views were incorporated in the questionnaires.

Data regarding the risk and success of computerised systems were obtained through questionnaires.

These questionnaires made use of a 7-point scale such as the following example:

Do you think networks constitute a big risk in computer systems?

small risk **1 2 3 4 5 6 7** big risk

Although no direct questions were used in the questionnaire but rather statements of characteristics that should be rated, it works on exactly the same principle.

The 7-point scale was used in research in the past [5], [55] and proved that this was an ideal scale to record perceptions.

With regard to the contents of the questionnaire care was taken not to have constant high-low questions. In some questions a 7 indicates a 'high' or 'good' while a 7 in other questions would mean a 'bad' or 'low'.

The data pertaining to the importance of systems were obtained by allocating weights through pair-wise comparisons. This method was discussed in chapter 2 and has already proven in practice to be a reliable and scientific method.

4.3.2.1 Obtaining of data regarding the risk of a system

The questionnaire to obtain data in respect of risk for each system consisted initially of seven factors which were rated. Based on that, an overall risk evaluation was given. The discussion of the processing and analysis of data in the next chapter will provide reasons and answers as to why this questionnaire was changed. In short, these seven factors did not include sufficient state variables to provide a profile of each system. Once these state variables had been included all of them were rated as the main risk determining factors. This was unacceptable as you can do little or nothing to a state variable. A state or uncontrollable variable may be defined as a variable which is not under the control of the researcher [7]. As opposed to decision variables these variables are difficult and sometimes impossible to adjust. It was then decided to design a form consisting of two parts. The first part gave the rating of the state variables and based on these ratings it also contained a risk rating. The second part then presented the respondent with the original rated seven factors. This then serves as provision made in an attempt to keep the risk of the specific system under control. Based on this degree of controls, provisions made, etc. as well as the original risk rating the respondent had to give a new risk rating. This new risk rating then was the final figure obtained to be used in the models.

Ratings were obtained as follows:

- The project leader, or project manager from the data centre in some cases, responsible for the development, implementation and maintenance of the specific system provided the ratings for the seven state variables.

  An overall risk rating for each system was also given by these personnel.

- Next, a rating for the seven factors (provisions or controls) was then obtained from the same EDP personnel.

- Finally a new risk rating (or a changed risk rating) for every system was obtained from:
  * A senior EDP Manager
  * A "main" user (this term is explained in chapter 1)
  * An independent consultant from outside the organisation.

The mean rating was used in the models.

4.3.2.2 Obtaining of data regarding the success of the system

A questionnaire with eight success factors rated on the 7-point scale was presented to respondents to evaluate each system's success.

Ratings were obtained as follows:

- The project leader, or project manager in some cases, from the data centre responsible for the development, implementation and maintenance of the specific system provided the ratings for the eight factors.

- Based on this rating an overall success evaluation was provided by a Senior EDP Manager and a "main" user. The mean of these two ratings was used as input to the model.

In the introductory chapter of this study input from users was mentioned as a major problem. Due to geographical problems, personnel from the EDP Centre had to act as users and to rate the factors based on their experience and interaction with users. This was also the reason for making use of the so-called "main user" for the second ratings. As the objective was not to establish success factors and ratings for specific systems for general use but to obtain information pertaining to a specific environment in order to develop a model for general use, the writer believed that this way of obtaining success ratings would suffice.

4.3.2.3 Obtaining of data regarding the importance of a system

In order to prioritise the different computer systems, pair-wise comparisons were carried out and weights from an importance scale were allocated to each system. A technique, described later in this chapter, was then used to finally prioritise the different systems.

Pair-wise comparisons were obtained from:

- A senior EDP manager
- A "main" user
- An independent consultant from outside the organisation.

The mean of the final calculated prioritised factors was used for the models developed.

4.4 STATISTICAL AND OTHER TECHNIQUES USED

To process and analyse all data obtained, various statistical and other techniques were used of which the most important will be briefly discussed. Comprehensive discussions and proofs for theorems can be found in the literature which will be referenced in the following concise discussion.

4.4.1 Computer software used

Other tools used for the processing of data naturally included computer software which also warrants mentioning. The following was used:

(i) SAS [78]

The SAS System is a software system for data analysis. It provides tools for:

- Information storage and retrieval
- Data modification and programming
- Report writing
- Statistical analysis
- File handling

Certain statistical analysis procedures were used in this research project. These procedures are among the finest available and range from simple descriptive statistics to complex multivariate techniques. Comprehensive discussions on the procedures used can be found in [95].

The following procedures were used:

- LP

  The LP procedure solves linear programs, integer programs and mixed integer programs. It also performs parametric programming, range analysis and reports on solution sensitivity to changes in the right hand side of equations, constants and coefficients.

- CORR

  The CORR procedure computes correlation coefficients between variables, including Pearson product-moment and weighted product-moment correlations.

  Correlation measures the closeness of a linear relationship between two variables. If one variable x can be expressed exactly as a linear function of another variable y, then the correlation is 1 or -1, depending on whether the two variables are directly related or inversely related. A correlation of zero between two variables means that each variable has no linear predictive ability for the other. If the values are normally distributed, then a correlation of zero means that the variables are independent of one another.

- RSQUARE

  The RSQUARE procedure selects optimal sub-sets of independent variables in a multiple regression analysis. Regression coefficients and a variety of statistics useful for model selection can be printed or output to a SAS dataset.

- REG

  The REG procedure fits linear regression models by least-squares. Sub-sets of independent variables that 'best' predict the dependent variable can be determined by various model-selection methods. The selection methods used in this study were:

FORWARD	:	Forward selection. The method starts with no variables in the model and adds variables.
BACKWARD	:	Backward elimination. The method starts with all variables in the model and deletes variables.
STEPWISE	:	Stepwise regression. This is similar to FORWARD except that variables already in the model do not necessarily stay there.
MAXR	:	Forward selection to fit the best one-variable model, the best two-variable model, and so on. Variables are switched so the R^2 is maximised.

(ii) <u>QUATTRO PRO</u> [90]

Quattro Pro is an electronic spreadsheet and can be regarded as a computerised version of a manual spreadsheet. It runs on a Personal

Computer and was mainly used because of its graphic capabilities as well as the ability to perform matrix operations and solve basic linear optimisation problems.

(iii) MATLAB [59]

MATLAB is a computer program which is classified as SHAREWARE. This means it is copyrighted software distributed in an unconventional manner. The authors allow (and encourage) the copying of their software so that as many people as possible can try them out. However, such programs are not free and the authors expect compensation should you use the program regularly. Serious shareware represents as much programming effort as conventional commercial products.

The name MATLAB was derived from 'Matrix Laboratory' and its capabilities range from standard tasks such as solving simultaneous linear equations and inverting matrixes, through symmetric and non-symmetric eigenvalue problems, to fairly sophisticated matrix tools such as the singular value decomposition.

The program features full online help and a very comprehensive user's manual. It was used in this study to calculate eigenvectors and eigenvalues.

4.4.2 Statistical techniques used

During the processing of data two statistical techniques were used which will be discussed in short. They are correlations and multiple linear regression. Numerous good handbooks exist which describe these methods in full [49], [84] and for the sake of completeness the summarised discussions as given by *Bruwer* [5] will be repeated here.

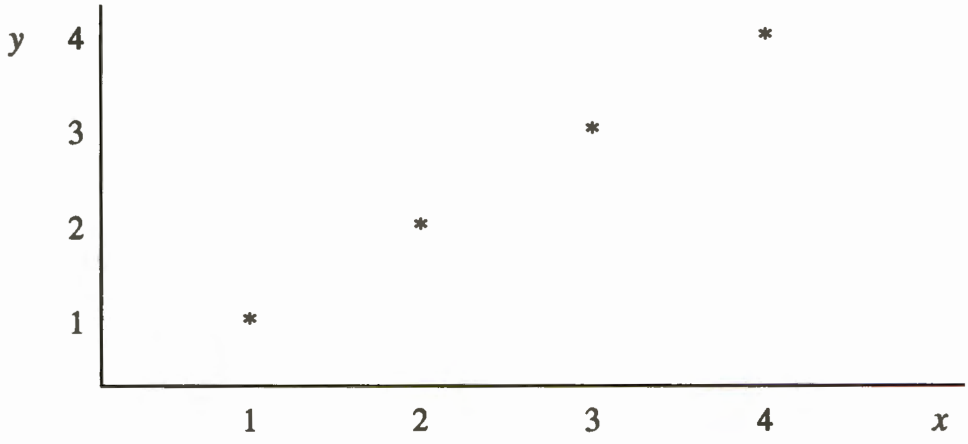
4.4.2.1 Correlations

4.4.2.1.1 The correlation coefficient

This discussion will be limited to linear relationships between two variables.

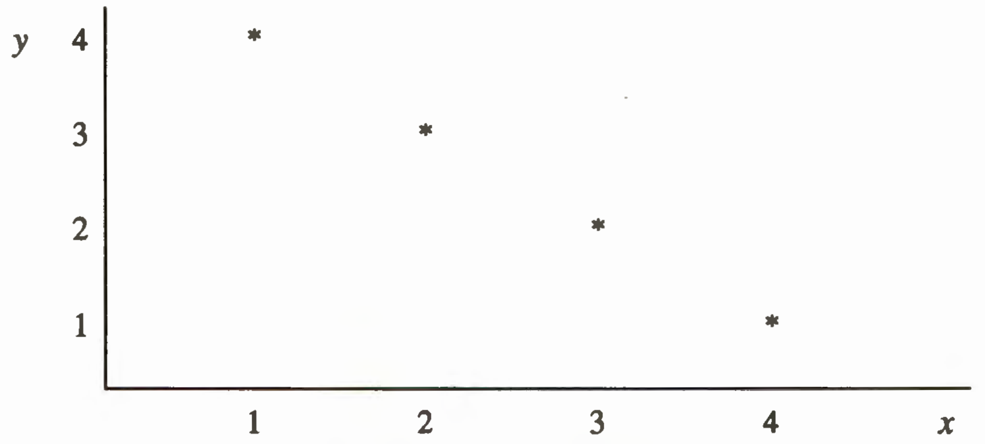
The extent to which one variable is dependent on another is often measured using correlation analysis.

Consider a case where there is a perfect positive relationship between two variables x and y.



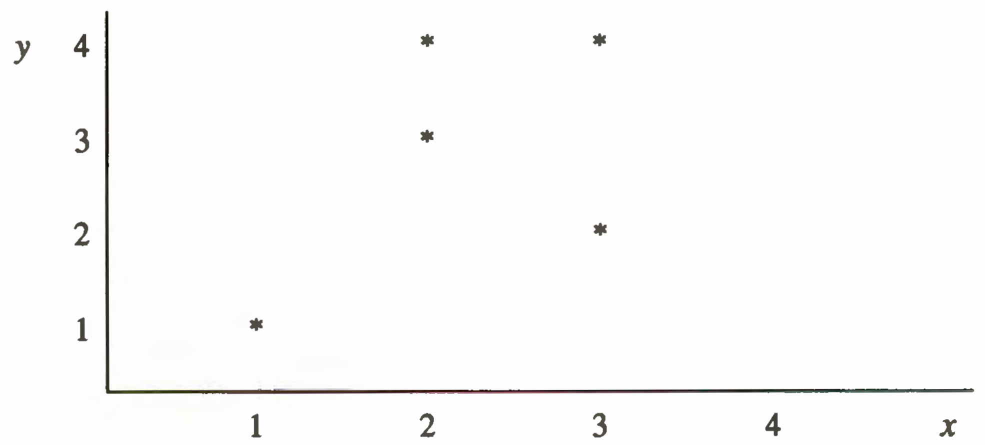
Perfect positive relationship

In this case the correlation coefficient will be exactly 1.00. The following shows the case where there is a perfect negative relationship between the two variables and the correlation coefficient for it will be -1.00.

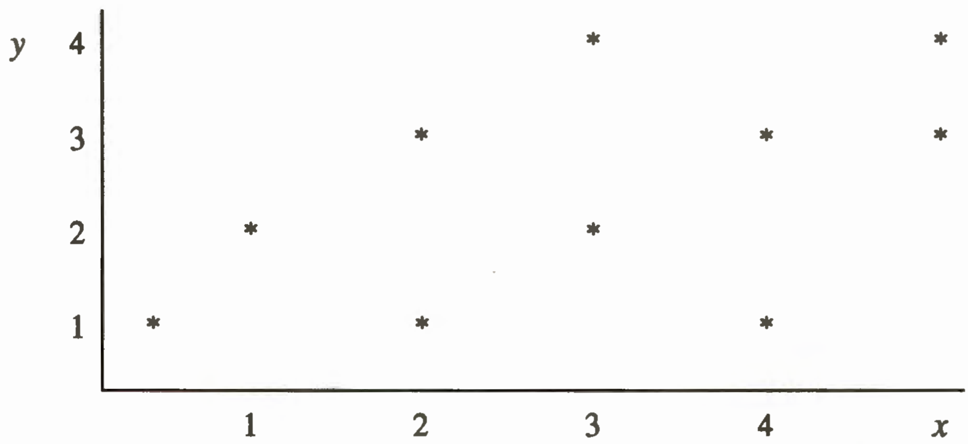


Perfect negative relationship

In general there will not be a perfect positive or negative relationship between the variables in which case the correlation coefficient would be somewhere between -1.00 and +1.00. In these cases the scatter diagrams may look like the following:



Non-perfect relationship



Non-Perfect relationship

4.4.2.1.2 Correlation coefficient formula

The correlation coefficient may be defined as the covariance of x and y divided by the standard deviation of x times the standard deviation of y.

$$r = \frac{C_{XY}}{S_X S_Y}$$

It can be verified in the literature that this formula can be written as:

$$r = \frac{[\Sigma(x-\bar{x})(y-\bar{y})/n]}{[\sqrt{\Sigma(x-\bar{x})^2/n}][\sqrt{\Sigma(y-\bar{y})^2/n}]}$$

This correlation coefficient is calculated to show the extent of relationship between two variables. It enables us to quantify the correlation between variables.

4.4.2.1.3 The coefficient of determination

The square of the value of r is called the coefficient of determination and is generally expressed as a percentage. It can be regarded as the percentage of change in y resulting from the change in x.

4.4.2.2 Multiple linear regressions

Comprehensive explanations may be found in the literature on multiple linear regressions [17], [49], [84]. As in the case of correlations the work on multiple linear regression quoted by *Bruwer* [5] is summarised here for completeness' sake.

Suppose a number of factors, say n, exist. For each factor consisting of a number of variables measurements are available for each variable. Furthermore, suppose that one of these variables is of primary concern to us and we want to forecast this specific variable in terms of a linear combination of the other variables. We then refer to this variable (which we want to forecast) as variable Y and to the remaining k variables as the X variables. This results in a multiple regression expression:

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots + b_kX_k$$

The problem is to find values for b_0, b_1, ..., b_k in such a way that the highest possible positive correlation between the observed values of Y and the forecast values of Y (indicated by Y') will be obtained. The resulting correlation coefficient between Y and Y' is then called a multiple correlation coefficient and is denoted by R_{yy^1}.

Calculation of b_0, b_1 and b_2 in a two variable model:

With two X - variables the regression equation becomes

$$Y' = b_0 + b_1X_1 + b_2X_2$$

The maximum coefficient of correlation between the observed Y - values and the forecast Y - values, Y', will be found when b_0, b_1 and b_2 are calculated such that the sum of the squares of the errors of the forecast values are minimised or:

$$SS_{res} = \Sigma(Y-Y')^2$$

The value of b_0 is given by:

$$b_0 = \bar{Y} - b_1\bar{X}_1 - b_2\bar{X}_2$$

Substitution of this expression into the regression equation resulted in:

$$Y' = \bar{Y} + b_1(X_1-\bar{X}_1) + b_2(X_2-\bar{X}_2)$$

or

$$Y' = \bar{Y} + b_1X_1 + b_2X_2$$

If the sum of the squared residuals are minimised, then b_1 and b_2 should satisfy the following:

$$\Sigma x_1y = b_1 \Sigma x_1^2 + b_2 \Sigma x_1x_2$$

and

$$\Sigma x_2y = b_2 \Sigma x_2^2 + b_1 \Sigma x_1x_2$$

We now have two equations with two unknown variables which can be solved using standard algebraic methods.

$$\therefore \; b_1 = \frac{(\Sigma x_1 y)(\Sigma x_2^2) - (\Sigma x_2 y)(\Sigma x_1 x_2)}{(\Sigma x_1^2)(\Sigma x_2^2) - (\Sigma x_1 x_2)^2}$$

and

$$b_2 = \frac{(\Sigma x_2 y)(\Sigma x_1^2) - (\Sigma x_1 y)(\Sigma x_1 x_2)}{(\Sigma x_1^2)(\Sigma x_2^2) - (\Sigma x_1 x_2)^2}$$

Interpretation of R^2

In the case of multiple linear regression, R^2 indicates the percentage variation of the dependent variable explained by the independent variables.

4.4.3 Other techniques used

Other techniques in this study include an optimisation technique developed by *Bruwer and Hattingh* [7] as well as a technique used to measure perceived importance of systems in order to prioritise them.

4.4.3.1 Optimisation of linear regression models

On its own, a linear regression model of the form:

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots + b_kX_k$$

does not offer much information. It is possible to see from the given model that:

- *Y* is a linear function
- *Y* is dependent on the different variables $X_1 \ldots X_k$

It is, however, impossible to forecast straight away that the value of Y can be increased by increasing those variables with positive coefficients and decreasing those with negative coefficients. It would also be incorrect to assume that *Y* can be increased by changing only one or two variables. The reason for this is the interdependence among the $X_1 \ldots X_k$ variables. When one of these variables is changed it will influence one or more of the other variables. A practical example of this can be found in *Bruwer* [5].

A technique where this interdependency is taken into account was developed by *Bruwer and Hattingh* [7]. In this technique a linear programming model was developed for decision-making.

A summary of the technique is as follows:

- Obtain a regression model that is "satisfactory".
- Determine the area of experience of the regression model by identifying the convex hull of the available data points.
- Identify the state variables whose influence on the dependent variable have to be investigated.
- Select a specific level for this variable.
- Optimise the regression function over the area within the convex hull where this variable is at a specific level. Obtain maximum and minimum values. Select another level and repeat the procedure.

- Graph the optimum values (maximum and minimum) of the regression function against different levels of the chosen variable.

The optimisation of a linear regression model means that a linear program has to be solved.

Optimisation problems are problems where a maximum or minimum value of a numerical function with a number of variables, subject to certain constraints, has to be computed.

Comprehensive discussions on linear programming could be found in various literature sources [19], [37], [69].

Chapter 6, which deals with the optimisation of the linear regression models found in this study, will elaborate on the formulation of a linear programming problem specific to the data and models in this research project.

4.4.3.2 Evaluating importance

Chapter 3 contains detail discussions on the various methods for prioritising systems, among others the method developed by *Saaty* [76] which was used in this study.

A brief description of the method as described by *Patton et al.* [66] is quoted here.

The relative importance and extent of computerised systems can be measured in many ways. In this study pair-wise comparisons of the systems were used. These comparisons depend on the judgement of individuals. The scaling technique extracts the most consistent measurement scale from these judgements; however, it requires a fair amount of calculation.

Saaty [73] developed an effective method of producing useful metric-measurement scales from paired-comparison data. The paired-comparison method involves constructing matrices whose entries represent an individual's estimate of the relative dominance of one element over another with respect to a given dimension. For example, in comparing efficiencies of divisions A and B, a matrix entry of 2 might indicate that division A was perceived to be slightly more efficient than division B, whereas an entry of 5 would indicate that division A was more efficient than division B.

An underlying measurement scale of perceived efficiency can be produced from a set of paired-comparisons by using the normalised principal eigenvector of the paired-comparison matrix. Intuitively, the scale is related to the "characteristic equation" of the comparison matrix. The equation explains or summarises the underlying relationships which are contained in the matrix.

The following Table 4.1 [75] defines an appropriate scale to use in judging the relative importance of one system over another:

Table 4.1 [75]

Importance Scale

Value Assigned	Definition	Explanation
1	Equal importance	The two systems are equally important in meeting the objectives of the respondent
3	Slightly more important	Experience and judgement suggest that one system is slightly more important than the other
5	Strongly more important	Experience and judgement indicate that one system is considerably more important than the other
7	Demonstrably more important	One system is strongly more important and this importance has been demonstrated
9	Absolutely more important	The evidence showing one system to be strongly more important is of the highest order of affirmation
2,4,6,8	Intermediate values	

Note: Reciprocals of the values above are assigned so that, if system 1 has a given number assigned when compared with system 2, system 2 has the reciprocal of that value when compared with system 1.

A sample of a comparison matrix for systems is shown in Table 4.2. Each matrix element reflects an individual's estimate of the relative importance of the row-system over the column-system by using the scale from Table 4.1.

Table 4.2

Sample of System Comparison Matrix*

	S1	S2	S3	S4
S1	1	5	2	8
S2		1	1/2	3
S3			1	6
S4				1

* Entries below the diagonal are constrained to be reciprocals of the corresponding entries above the diagonal. Entries reflect the relative importance of the system in the row over the system in the column.

In Table 4.2, system 1 is judged to be strongly more important than system 2 (assigned value of 5); and system 2 is judged to be slightly more important than system 4 (assigned value of 3).

The basic scaling problem is to derive from the paired-comparison matrix the set of importance weights which is most consistent with the judgements contained in that matrix. The solution to this scaling problem is to use the vector (set of values) associated with a characteristic value of the matrix. When this vector is normalised to sum to one, the solution is unique. The elements of this scale vector are a numerical measure of the individual's perceptions of the relative importance of the systems.

The mathematical details of Paired-Comparison Scaling Technique, also quoted from *Paton et al.* [66], are as follows:

The basic scaling problem is to extract a vector of weights $\underline{w} = (w_1, w_2, \ldots w_n)$ from our n x n pair-wise comparison matrix A. To simplify the derivation and explanation of the proposed scaling technique, we first consider a perfectly consistent judgement matrix X in which $x_{ij}x_{jk} = x_{ik}$ for every i, j and k. Note that this definition implies a matrix with the following:

* Cardinal and ordinal transitivity
* Diagonal values of unity
* The reciprocal property $1/x_{ij} = x_{ji}$
* Precise estimates of $\underline{w}$, where $x_{ij} = w_i/w_j$

For this consistent matrix, simple matrix algebra shows that $X\underline{w} = n\underline{w}$. This result is clear if we write each x_{ij} in X as the ratio w_1/w_2 and postmultiply X by $\underline{w}$ to obtain $n\underline{w}$. To extract the unknown scale vector w, we must solve the system $(X - nI)\underline{w} = 0$, where I is the n x n identity matrix. This system has a non-zero solution if, and only if, n is one of the characteristic roots (eigenvalues) of X. Since X is a perfectly consistent matrix, it has a unit rank and only one non-zero eigenvalue (λ_{max}). We also know that the sum of the eigenvalues ($\Sigma\lambda_i$) equals the trace (sum of the main diagonal elements) of the matrix.
Since $x_{ii} = 1$, the trace of X = n. Summarising, we know:

$$\lambda_i = 0 \text{ for } \lambda_i \neq \lambda_{max}$$

$$\Sigma\,\lambda_i = \text{trace X}$$

$$\text{trace X} = n$$

$$\text{therefore, } \lambda_{max} = n$$

Thus, n is an eigenvalue of X, and the system $(X - n)\ \underline{w} = 0$ has a non-zero solution. Because of the consistency of the matrix, the solution to the system in the unknown $\underline{w}$ is any row of X. If we normalise the solution to sum to one, the solution for $\underline{w}$ is unique: we have extracted the importance scale $\underline{w}$ from our matrix of paired comparisons.

In practice, we are not likely to get perfectly consistent comparative judgements from our subject. Although we can constrain subjects to consider the reasonableness of the reciprocal property, we may frequently find a lack of cardinal or ordinal transitivity. However, for minor deviations from consistency, λ_{max} remains near n; and the remaining eigenvalues remain close to zero. (This relationship forms the basis of a numerical index to measure the judgemental consistency of a subject.) In this general case, we must solve the system $(A - \lambda_{max}{}^{I})\underline{w} = 0$, where A is not perfectly consistent. In this system, we can no longer use any row of A as the solution $\underline{w}$. Rather, we must find a vector associated with the largest real eigenvalue, λ_{max}. When this vector is normalised to sum to one, the solution is unique.

An example of the above-mentioned problem (to extract a vector of weights, $\underline{w}$, from the n x n pair-wise comparison matrix) follows:

To solve this problem the system determinant $(A - nI)\underline{w} = 0$ must be solved:

$\underline{w}$: vector we are trying to compute

n : from the n x n matrix

A : The n x n pair-wise comparison matrix

I : The identity matrix e.g. $I_2 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

The determinant of the *n* x *n* matrix A (entries indicated by a_{ij}) is the expression det A = $\Sigma(-1)^x\ a_{1j_1}, a_{2j_2}, \ldots\ a_{nj_n}$ where the sum is taken over **all** permutations of x.

$$\text{let } A = \begin{bmatrix} 1 & 0 \\ 1 & 3 \end{bmatrix}$$

then

$$(A-nI) = \begin{bmatrix} 1 & 0 \\ 1 & 3 \end{bmatrix} - n \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1-n & 0 \\ 1 & 3-n \end{bmatrix}$$

The determinant would be (1-n)(3-n)
Solve (1-n)(3-n) = 0
that gives n=1 and n=3
These two values are the eigenvalues of A.

If you have a matrix with eigenvalue *n*, and a non-zero vector $\underline{w}$ can be computed such that A$\underline{w}$ = n$\underline{w}$ then $\underline{w}$ is said to be an eigenvector of the matrix A associated with the eigenvalue *n*.

We must find a vector associated with the largest real eigenvalue which in our example is 3.

The following must be solved:

$$\begin{array}{ccccc} A & & \underline{w} & = & n\underline{w} \\ \begin{bmatrix} 1 & 0 \\ 1 & 3 \end{bmatrix} & & \begin{bmatrix} w_1 \\ w_2 \end{bmatrix} & = 3 & \begin{bmatrix} w_1 \\ w_2 \end{bmatrix} \end{array}$$

This gives
$$\begin{aligned} w_1 &= 3w_1 \\ w_1 + 3w_2 &= 3\,w_2 \end{aligned}$$

It can be seen from these two equations that $w_1 = 0$ and w_2 may be any value.

In this example, let $w_1 = 0$ and $w_2 = 1$ then $\begin{bmatrix} 0 \\ 1 \end{bmatrix}$ will be the eigenvector associated with the eigenvalue 3.

4.5 SUMMARY

Chapter 4 gave a brief overview of the organisation where the research was conducted. A discussion of the various statistical and other techniques included optimisation problems as well as a method to rank systems according to their perceived importance. A very brief introduction to the different computer software and computer packages used during the study also formed part of the discussion.

CHAPTER 5

PROCESSING AND ANALYSIS OF DATA

5.1 INTRODUCTION

The analysis of data obtained during the research project will be discussed in this chapter. Correlations will be used to test whether certain relationships among variables exist and then, by using linear regression, the linear relationships will be established. A discussion of the prioritising of systems will complete this chapter.

5.2 RISK

5.2.1 Initial fieldwork

Previous chapters already discussed risk factors relating to computerised systems. These researched factors were used as a basis for drawing up an informal list of factors which could possibly influence a computerised system. This list in turn, was used as a discussion document to establish, through interviews, the most important factors specific to our organisation.

Informal discussions were also held with EDP personnel in order to draw from their vast experience as well as to make sure that the identified factors relate specifically to our organisation and its environment.

Table 5.1 gives a list of risk factors, identified by EDP personnel, which are specific to the organisation's environment where the study was conducted. This list, together with the factors identified from the literature and other discussions, was used to draw up a list of eight factors supposed to be used to develop a model. These initial eight factors are given in Table 5.2.

Table 5.1

Risk factors identified through informal discussions which related specifically to our organisation

System failure
Changes to a system
Other equipment used in conjunction with the computer system, e.g. card readers
Ability of users to learn and use the system
Technical issues, e.g. impact on other systems
Logical and physical security
Operate outside time budgets
Outside money budgets
Non-compliance with user requirements

An interesting fact, specific to this organisation, is that certain systems are always considered high risk systems without taking any other factor into account. This is due to possible industrial relationship problems, loss of money as well as loss of physical assets, if these certain systems are not operational.

Table 5.2

Initial 8 risk factors

1	Training EDP personnel who have undergone or are at present receiving (including continuous)
2	How managers (EDP and Users) act e.g. support, attitude, etc
3	Communication between DP Department and users
4	Technology used
5	Physical security
6	Logical security and quality of internal controls
7	Integration with and impact on other systems
8	Recent changes to systems or key personnel

From this list, only factor 7 was regarded as a state variable which means that this factor is a given situation and could not be varied.

Twenty-six case studies were initially regarded as sufficient and for each of the twenty-six systems the 8 factors were rated as described in Chapter 4. They were then sent to a consultant for evaluation of completeness. With each case study a brief description was included in order for the consultant to "get a feel" for the system. An example of such a brief system description was as follows:

The system is a materials control system that is an integrated Stores, Purchasing and Creditors' System. The major objective is to provide a high level of materials availability at an acceptable cost.

The main features of the system are:

- *Stock control for different stores*
- *Automatic standard stock ordering*
- *Integrated Creditors and Accounts Payable*
- *On-line facilities (enquiry at all levels, goods receiving, special ordering and purchasing information capturing)*
- *Comprehensive reporting (daily, weekly, monthly, yearly and on request)*
- *Management reporting and statistics*

The system interfaces with:

- *A Stores Control System on a monthly basis*
- *A General Ledger System on a daily and weekly basis*
- *Systems located at the company's Head Office*

The system comprises of ± 500 Cobol programs as well as numerous programs developed with 4GL's.

The consultant felt that the 8 factors were insufficient and suggested that we add two others, viz.:

- Need to maintain confidentiality, manipulation or availability of data or system.
- Threat of breaching confidentiality, manipulation or availability of data or system.

This was unacceptable as it was felt that rating these two factors would be the same as rating the risk of a system. The two factors were too close to risk and could be seen as the same issue and therefore confusing the people who were responsible for the ratings of each factor.

5.2.2 Importance as a factor

The original 8 factors, as per Table 5.2, plus the mentioned brief description for each system, were then sent to another consultant for evaluation. Although the importance of systems is treated in a different way, as discussed later in this chapter, it was decided to experiment with this issue and also asked for an importance rating. The consultant, therefore, had to rate the system's risk and importance on a 7 point scale, based on the given factors and their ratings, as well as the short description. The reason for including importance in the questionnaire was because it was felt that importance may act as a factor influencing the system's risk. An overall risk and importance assessment for each system was also obtained from the EDP centre.

Using the RSQUARE procedure provided by the SAS System the following results were obtained:

Importance included as a factor

NUMBER OF VARIABLES IN MODEL	R^2 OBTAINED FROM EDP PERSONNEL'S RATINGS	R^2 OBTAINED FROM CONSULTANTS RATING	R^2 OBTAINED BY USING AVERAGE RATING OF EDP PERSONNEL AND CONSULTANTS
1	0,238	0,394	0,198
2	0,384	0,514	0,454
3	0,476	0,587	0,641
4	0,510	0,633	0,661
5	0,526	0,681	0,678
6	0,546	0,699	0,696
7	0,551	0,729	0,724
8	0,555	0,741	0,731
9	0,556	0,745	0,733

Importance excluded as a factor

NUMBER OF VARIABLES IN MODEL	R^2 OBTAINED FROM EDP PERSONNEL'S RATINGS	R^2 OBTAINED FROM CONSULTANTS RATING	R^2 OBTAINED BY USING AVERAGE RATING OF EDP PERSONNEL AND CONSULTANTS
1	0,238	0,208	0,178
2	0,384	0,398	0,265
3	0,427	0,467	0,399
4	0,442	0,566	0,487
5	0,451	0,643	0,554
6	0,463	0,677	0,594
7	0,466	0,727	0,615
8	0,466	0,729	0,627

Although R^2 could be improved from 0,627 to 0,733 by including Importance as a factor influencing risk, it was decided to exclude Importance as a factor due to the following reasons:

- Importance showed a strong correlation with risk factor 7 (Integration with and impact on other systems) [R^2 = 0,713]. This means that variation in the dependent variable explained by the factor Importance could almost equally be explained by risk factor 7.

- Through personal interviews it was established that Importance and Risk confused the respondents. In most cases it was intuitively seen as the same issue and had a great influence on the way of reasoning and could therefore not be regarded as a reliable rating.

It was thus decided to handle Importance as a completely different issue which is described comprehensively in earlier chapters as well as later in this chapter (5.4).

Another interesting fact that came to light after this exercise was that the brief description for each system was a major factor contributing to unreliable ratings. Whenever it could be seen from the description that the case study is a so-called 'important' system (e.g. Payroll) it was rated as very important with a high risk **regardless** of the ratings given for the 8 factors.

This problem was overcome by adding state variables to the questionnaire and getting rid of the brief system description.

5.2.3 Incorporation of state variables

The purpose of the state variables was to provide the respondents with a profile of the system rather than an explicit description which enabled them to identify systems.

It was felt that it would be possible to identify a great number of state variables and in order to obtain the ones most significant to our organisation, the identification process was done through informal discussions and interviews. This process resulted in 6 state variables which were added to the questionnaire for a total of 14 factors. Table 5.3 contains the 6 state variables.

Table 5.3

State variables added to questionnaire to provide a profile of the system

1	Influence of Acts of God (natural disasters) e.g. lightning, earthquakes, fires, etc.
2	Influence of change in Government Regulations (e.g. VAT) union policies, company policies, etc.
3	The degree of dependence on external sources, e.g. vendor support, international standards, Post and Telecommunications, quality of products purchased, etc.
4	The system's relationship with personnel issues, e.g. strikes, industrial relations, deliberate actions, (e.g. vandalism) epidemic diseases, etc.
5	The criticality of the period when the system has to be operational, e.g. daily, monthly, 24 hours a day, etc.
6	The degree to which the system is linked to valuable assets and operates on sensitive data and future action by management may also be heavily dependent upon the information produced by the system.

An increase in the number of factors from 8 to 14 warrants an increase in the number of case studies and therefore an extra 10 systems were chosen to add to the already chosen case studies for a total of thirty-six systems.

Evaluations, on the 7-point scale for the added 6 factors were obtained from the EDP centre and an overall risk rating, based on the given 14 factors' rating, for each system was then obtained as described in Chapter 4.

Using the RSQUARE procedure provided by the SAS System the following results were obtained:

NUMBER OF VARIABLES IN MODEL	R^2 OBTAINED FROM EDP PERSONNEL'S RATINGS	R^2 OBTAINED FROM CONSULTANTS RATING	R^2 OBTAINED BY USING AVERAGE RATING OF EDP PERSONNEL AND CONSULTANTS
1	0,653	0,847	0,834
2	0,802	0,920	0,874
3	0,862	0,941	0,909
4	0,901	0,952	0,933
5	0,922	0,956	0,946
6	0,934	0,959	0,955
7	0,946	0,962	0,967
8	0,951	0,963	0,970
9	0,955	0,965	0,971
10	0,956	0,965	0,973
11	0,957	0,966	0,974
12	0,957	0,966	0,975
13	0,958	0,966	0,975
14	0,958	0,966	0,975

All the R^2-values obtained were almost alarmingly good. A closer look at which factors were added to the model each time will show that the risk of systems is, according to the ratings, almost entirely determined by the state variables. The following summaries of the first 5 variables that are entered into the system explain the above statement.

EDP Personnel's Ratings:

NUMBER OF VARIABLES IN MODEL	NUMBER OF STATE VARIABLES	NUMBER OF DECISION VARIABLES
1	1	0
2	2	0
3	2	1
4	3	1
5	4	1

Consultant Ratings:

NUMBER OF VARIABLES IN MODEL	NUMBER OF STATE VARIABLES	NUMBER OF DECISION VARIABLES
1	1	0
2	2	0
3	3	0
4	4	0
5	5	0

Average Ratings for EDP Personnel and Consultants:

NUMBER OF VARIABLES IN MODEL	NUMBER OF STATE VARIABLES	NUMBER OF DECISION VARIABLES
1	1	0
2	2	0
3	3	0
4	3	1
5	4	1

The conclusion drawn from these results was that the respondents identified the newly added state variables as very important and therefore concentrated on them when giving their overall risk rating. This situation was unacceptable as one can do very little or nothing to change state variables. A method to force the respondents to base their evaluations on the decision variables had to be found.

To overcome this problem the questionnaire was divided into two sections. The first section contained the 7 state variables and how they were rated (the original state variable - factor 7 in Table 5.2 - included) plus the risk of the system based on these state variables. In other words, a profile of the system plus the system's risk, as rated by them, was given to them. The second part of the questionnaire contained the remaining 7 decision variables and how they were rated. The decision variables were then considered as the degrees of provisions made in an attempt to keep the risk of the system under control. The respondents then had to give a new risk rating based on the degree of controls, provisions made, etc. (decision variables). In doing so, they basically have to answer the following:

> *Given the risk of a system, which is based on 7 state variables, and given the degree of provisions made, controls, etc. (the rated 7 decision variables) are you prepared to give a new risk rating?*

New risk ratings were then obtained as described in Chapter 4. The factors on which this new risk rating was based were the old risk rating (based on the state variables) and the 7 decision variables.

The 7 decision variables were rearranged on the new questionnaire and in the correlation analysis are denoted as F_1, F_2 ... F_7

F_1 - Physical security

F_2 - Technology used

F_3 - Training EDP personnel who have undergone or are at present receiving (including continuous)

F_4 - Recent changes to system or key personnel

F_5 - How managers (EDP and Users) act, e.g. support, attitude, etc.

F_6 - Communication between DP Department and users

F_7 - Logical security and quality of internal controls

Using the RSQUARE procedure provided by the SAS System the following results were obtained:

NUMBER OF VARIABLES IN MODEL	VARIABLES IN MODEL	R^2
1	F_4	0,550
2	OldRisk, F_5	0,670
3	OldRisk, F_4,F_5	0,835
4	OldRisk F_1,F_4,F_5	0,881
5	OldRisk, F_2,F_4,F_5,F_6	0,923
6	OldRisk, F_2,F_3,F_4,F_5,F_6	0,940
7	OldRisk F_1,F_2,F_3,F_4,F_5,F_6	0,948
8	OldRisk, F_1,F_2,F_3,F_4,F_5,F_6,F_7	0,949

A correlation analysis resulted in the following correlation matrix:

Correlation Analysis - Risk

	NewRisk	OldRisk	F_1	F_2	F_3	F_4	F_5	F_6	F_7
NewRisk	1,00000	0,40533	-0,20772	0,02262	-0,15089	0,74170	-0,51201	-0,21045	0,03022
OldRisk	0,40533	1,00000	0,30490	0,29046	0,19492	0,24069	0,36813	0,46292	0,42427
F_1	-0,20772	0,30490	1,00000	0,21775	0,07323	0,06440	0,34263	0,44791	0,55021
F_2	0,02262	0,29046	0,21775	1,00000	0,02278	0,11919	-0,01194	-0,03414	0,40550
F_3	-0,15089	0,19492	0,07323	0,02278	1,00000	-0,08105	0,49677	0,40653	0,08888
F_4	0,74170	0,24069	0,06440	0,11919	-0,08105	1,00000	-0,28396	0,05156	0,28294
F_5	-0,51201	0,36813	0,34263	-0,01194	0,49677	-0,28396	1,00000	0,56721	0,24884
F_6	-0,21045	0,46292	0,44791	-0,03414	0,40653	0,05156	0,56721	1,00000	0,45095
F_7	0,03022	0,42427	0,55021	0,40550	0,08888	0,28294	0,24884	0,45095	1,00000

The conclusion from all the results mentioned thus far would be that:

$$\text{Risk} = f(\text{OldRisk}, F_1, F_2, F_3, F_4, F_5, F_6, F_7)$$

and the complete regression equation would be:

$$\text{Risk} = 3{,}3050 + 0{,}3497\text{OldRisk} - 0{,}0793F_1 - 0{,}1400F_2 + 0{,}0634F_3 + 0{,}1960F_4 - 0{,}2120F_5 - 0{,}1486F_6 - 0{,}0093F_7$$

with $R^2 = 0{,}949$

5.2.4 Reducing the number of independent variables

It is desirable to reduce the number of independent variables to as low as possible but with the R^2-value as high as possible, the reason being that only those variables with a significant contribution in determining the dependent variable should be used in a model. Furthermore, the model should be kept as simple as possible.

The method developed to reduce the 8 independent variables was to make use of a graphic representation to determine whether independent variables did exist which made an insignificant contribution to the R^2-value. Figure 5.1 is a graphic representation of the number of variables (*N*) and the corresponding R^2-values.

It can be seen that the contribution to the R^2-value is very small when adding a 7th or 8th variable (less than 1%). The REG procedure provided by the SAS System was then used with the FORWARD, BACKWARD, MAXR and STEP-WISE options (discussed in Chapter 4) to determine the "best" sub-set of six variables out of the original 8 variables. The sub-set found contained 6 variables and is given in Table 5.4.

Figure 5.1 - Risk Model

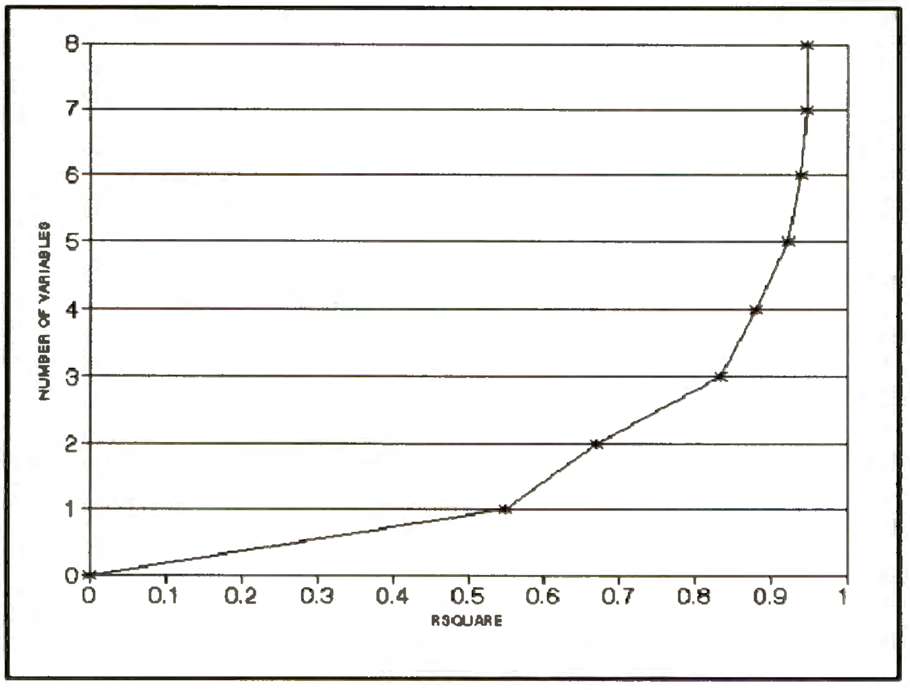


Table 5.4
Dependent Variable = Risk
R^2 = 0,94

INDEPENDENT VARIABLE	COEFFICIENT
Y-Intercept	3,3961
OldRisk	0,3440
F_1	-0,1018
F_2	-0,1345
F_4	0,1976
F_5	-0,1869
F_6	-0,1316

94% of the variation in Risk is explained by these six independent variables and the regression equation now becomes:

$$Risk = 3{,}3961 + 0{,}3440OldRisk - 0{,}1018F_1 - 0{,}1345F_2 + 0{,}1976F_4 - 0{,}1869F_5 - 0{,}1316F_6$$

with the F-test: 72,28 with probability >F 0,0001

To conclude, an adequate model, explaining 94% of the variation in the risk, could be found using the six factors:

- Profile risk based on state variables
- Physical security
- Technology used
- Recent changes to system or key personnel
- How managers (EDP and Users) act, e.g. support, attitude, etc.
- Communication between DP Department and users

5.3 SUCCESS

5.3.1 Initial fieldwork

Many research exercises have been performed in the past to identify success factors for computerised systems. Some of these research projects were referenced and discussed in earlier chapters.

As seen from these earlier discussions (Chapter 3), success is an important aspect which should not be neglected. The fact that there may be certain cases where virtually no risk is involved pertaining to computerised systems, does not automatically imply that these systems are successful. This proves the interest among researchers firstly to identify factors influencing a computerised system's success and secondly to design adequate tools and techniques to measure or quantify success. All these research projects have led to the situation where it is relatively easy to obtain information from literature regarding success of computerised systems as opposed to risk and importance and the factors influencing them.

Although it appeared as if success is something that may differ for each organisation, literature indicated that the factors generally apply to all systems and organisations. Due to this it was decided to choose the 39 factors identified by *Bailey* for use in the model (Chapter 3). The complete list of factors can be found in Appendix G.

To keep the model as simple as possible the 39 factors were divided into eight main factors. Each main factor comprises certain sub-factors chosen from the list of 39 sub-factors. The division of these factors was discussed in Chapter 3.

The correct procedure to evaluate these eight factors, for each system, would be to go to each user(s) of that specific system and ask them for an evaluation. However, the users were inaccessible due to the scope and geographical locations of the systems, as mentioned in Chapter 1, and we had to make use of EDP personnel. This would have no major negative influence on the correctness of evaluations as only experienced data-processing personnel were used in the exercise. There were no programmers involved and all EDP staff, used as respondents, were either project leaders or project managers who had a considerable number of years' experience relating to the specific system under review. This experience includes system development and project management as well as extensive liaison with all users involved in the specific system.

Furthermore, possible inaccurate evaluations by users, so often the result of only one incident such as an unforeseen disruption of services or breakdown of hardware, were eliminated by obtaining a more "objective" evaluation.

EDP personnel involved in each system gave a rating for the 8 factors based on their knowledge and experience with the actual users of the system. An overall success rating was then obtained for each system, based on the evaluated 8 factors. The obtaining of data was discussed in Chapter 4.

Using the RSQUARE procedure provided by the SAS System the following results were obtained:

NUMBER OF VARIABLES IN MODEL	VARIABLES IN MODEL	R^2
1	F_5	0,705
2	F_1,F_5	0,799
3	F_3,F_4,F_6	0,862
4	F_1,F_6,F_7,F_8	0,893
5	F_1,F_4,F_6,F_7,F_8	0,916
6	F_1,F_4,F_5,F_6,F_7,F_8	0,924
7	$F_1,F_3,F_4,F_5,F_6,F_7,F_8$	0,928
8	$F_1,F_2,F_3,F_4,F_5,F_6,F_7,F_8$	0,932

A correlation analysis resulted in the following correlation matrix:

Correlation Analysis - Success

	Success	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8
Success	1,00000	0,68825	0,29402	0,63659	0,81583	0,84015	0,69225	0,75624	0,71921
F_1	0,68825	1,00000	0,45784	0,65641	0,50296	0,50662	0,46239	0,35225	0,42112
F_2	0,29402	0,45784	1,00000	0,38623	0,06953	0,20406	0,36233	0,28499	0,16153
F_3	0,63659	0,65641	0,38623	1,00000	0,45516	0,48401	0,25604	0,47631	0,51918
F_4	0,81583	0,50296	0,06953	0,45516	1,00000	0,78924	0,47989	0,62237	0,67504
F_5	0,84015	0,50662	0,20406	0,48401	0,78924	1,00000	0,60578	0,68447	0,59974
F_6	0,69225	0,46239	0,36233	0,25604	0,47989	0,60578	1,00000	0,53751	0,27518
F_7	0,75624	0,35225	0,28499	0,47631	0,62237	0,68447	0,53751	1,00000	0,52767
F_8	0,71921	0,42112	0,16153	0,51918	0,67504	0,59974	0,27518	0,52767	1,00000

The conclusion from these results would be that:

$$\text{Success} = f(F_1, F_2, F_3, F_4, F_5, F_6, F_7, F_8)$$

and the complete regression equation would be:

$$\text{Success} = 1{,}1696 + 0{,}1306F_1 - 0{,}0805F_2 + 0{,}0928F_3 + 0{,}1333F_4 + 0{,}1062F_5 + 0{,}1552F_6 + 0{,}1509F_7 + 0{,}1487F_8$$

$$\text{with } R^2 = 0{,}932$$

5.3.2 Reducing the number of independent variables

As in the case with the risk model, it is desirable to reduce the number of independent variables to as low as possible but with a R^2 - value as high as possible.

The same method was followed as with the risk model to reduce the number of independent variables graphically. Figure 5.2 is the graphic representation of the number of independent variables and the corresponding R^2 values.

It can be seen that the contribution to the R^2 - value is very small when adding a 7th or 8th variable (less than 1%). The REG procedure provided by the SAS System was then used with the FORWARD, BACKWARD, MAXR and STEPWISE options (discussed in chapter 4) to determine the "best" sub-set of six variables out of the original 8 variables. The sub-set found contained 6 variables and is given in Table 5.5.

Figure 5.2 - Success Model

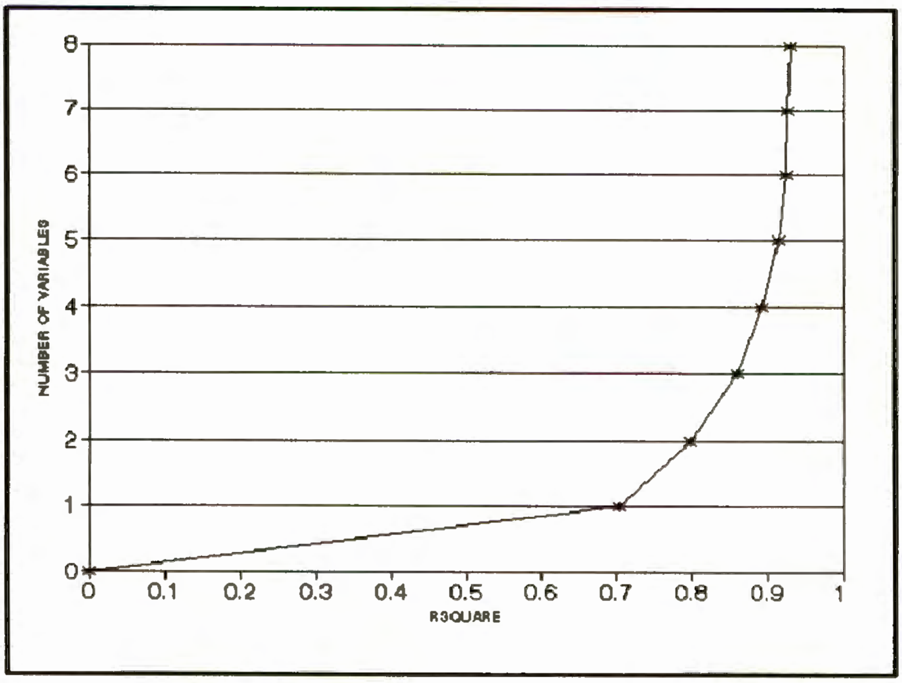


Table 5.5
Dependent Variable = Success
$R^2 = 0,92$

INDEPENDENT VARIABLE	COEFFICIENT
Y-Intercept	0,9926
F_1	0,1464
F_4	0,1536
F_5	0,1163
F_6	0,1305
F_7	0,1595
F_8	0,1583

92% of the variation in Success is explained by these six independent variables and the regression equation now becomes:

$$\text{Success} = 0{,}9926 + 0{,}1464F_1 + 0{,}1536F_4 + 0{,}1163F_5 + 0{,}1305F_6 + 0{,}1595F_7 + 0{,}1583F_8$$

with the F-test: 58,89 with probability > F 0,0001

5.3.3 Practical problems

The reaching of a satisfactory regression equation should complete this part of the research before optimisation techniques would be applied. However, a closer look at the success factors and their sub-factors indicated that practical problems could be experienced when trying to change these factors or allocate resources to them.

Consider, as an example, the factor F_7 - Issues concerning conventional system characteristics with its associated sub-factors. If the optimisation techniques, applied in the next chapter, indicated that F_7 should be improved, which one(s) of its thirteen sub-factors should be changed to improve F_7? One method to solve this problem could be to take these 13 sub-factors and prioritise them according to their perceived importance. This prioritising could be done using the same method developed by *Saaty* and used in this study to prioritise the systems according to their perceived importance.

Instead of prioritising all 39 sub-factors it was decided to rearrange these 39 factors into 4 main groups. These 4 main groups were then the only issues to be prioritised. The rearranged four groups of sub-factors were:

1. **User involvement**

   Feeling of control

   Feeling of participation

Expectations

Perceived utility

Confidence in the system

Understanding of the system

Degree of training

Job effects

Relationship with EDP staff

Communication with EDP staff

2. Issues related to end user computing

Convenience of access

Language

Relevancy

Documentation

Response/turnaround time

Means of input/output with EDP Centre

System output: Accuracy
Timeliness
Precision
Reliability
Currency
Completeness
Format
Volume

3. Technical characteristics

Technical competence of EDP staff

Flexibility of the system

Integration of systems

Error recovery

Security of data

Time required for new development

Processing of change request

Vendor support

4. Management and strategic issues

Top management involvement

Charge-back method of payment for services

Schedule of products and services

Organisational position of EDP function

Organisational competition with EDP staff

Attitude of EDP staff

Priorities determination

It would now be possible to rate the 4 main issues and again rate all the sub-factors within each group to get a prioritised list of factors within each group. For the purpose of this study and to keep the model as simple as possible, only the 4 main groupings were prioritised using exactly the same method used to prioritise the systems on their perceived importance. The same importance scale, described in Chapter 4, was used and resulted in the following comparison matrix:

Factor Grouping Comparison Matrix

	G_1	G_2	G_3	G_4
G_1	1,0000	3,0000	0,5000	0,5000
G_2	0,3333	1,0000	5,0000	3,0000
G_3	2,0000	0,2000	1,0000	0,5000
G_4	2,0000	0,3333	2,0000	1,0000

where G_1 = User involvement
G_2 = Issues related to end user computing
G_3 = Technical characteristics
G_4 = Management and strategic issues

The normalised eigenvector, associated with the above matrix's largest eigenvalue, serves as the scale and was the following:

GROUP	EIGENVECTOR	NORMALISED VALUE
G_1	0,1588	0,2734
G_2	0,2010	0,3461
G_3	0,0937	0,1613
G_4	0,1273	0,2192

It is clear from this scale that the perceived importance of the four main groupings is:

1. G_2 - Issued related to end user computing
2. G_1 - User involvement
3. G_4 - Management and strategic issues
4. G_3 - Technical characteristics

One can now argue that we had a most important group, G_2, consisting of 14 sub-factors, say numbers 1, 2, 3, ... 14.

A second most important group, G_1, consisting of 10 sub-factors, say numbers 15, 16, ... 24.

A third most important group, G_4, consisting of 7 sub-factors, say numbers 25, 26, ... 31.

A least important group, G_3, consisting of 8 sub-factors, say numbers 32, 33, ... 39.

To get back to the original problem where factor F_7 was shown to be the one which should be improved:

Take the thirteen sub-factors of F_7 and compare them to the new prioritised 4 main groupings of sub-factors. If a F_7 sub-factor corresponds to any of the 1 to 14 sub-factors (G_2), as explained above, then it should receive priority attention or resources. Likewise, if it corresponds to any of the numbers 32 to 39 (G_3) above, it should receive least attention. In this way a method to explain which sub-factors should receive attention was developed. The method is explained diagrammatically on the next page.

F_7 - Issues concerning conventional system characteristics		Four main groupings in order of importance
Sub-factors: Convenience of access Language Relevance Documentation Response/turnaround time	High Priority	**G_2 - Issues related to end user computing** Convenience of access Language Relevancy Documentation Response/turnaround time . . .
Expectations Undertaking of systems Perceived utility Confidence in the system	Middle/ Medium Priority	**G_1 - User involvement** Expectations Understanding of systems Perceived utility Confidence in the systems . . .
		G_4 - Management and strategic issues . . .
Flexibility of systems Integration of systems Error recovery Security of data	Low Priority	**G_3 - Technical characteristics** Flexibility of systems Integration of systems Error recovery Security of data . . .

5.4 IMPORTANCE

The importance of a system may be regarded as an attribute of that specific system. It may of course also be described by relationships among different variables or factors but as different organisations have different objectives and different interests it would be difficult to find such general factors.

It was, however, accepted in this study that certain relationships may exist among importance, risk and success of computerised systems. This would be especially true when allocating resources to various computer-based systems. A system with a high risk or low success rating but of no importance to the organisation should not receive many resources. On the other hand, a system which is extremely important to the organisation may be rated as fairly risky only due to its importance and then receive more resources. A system may also receive additional resources due to its importance while it may already be very successful with a low risk rating.

As in the case of risk and success factors, various ways of measuring and prioritising were discussed in Chapter 3. The technique, developed by *Saaty*, was chosen and the obtaining of data was described in Chapter 4.

During the initial stages of the study, twenty-six systems were used for evaluation (Paragraph 5.2 discussed reasons for change in number of systems during the research). These twenty-six systems were sent to a consultant for evaluation as described earlier. The reason for this exercise was to try and determine whether this would be a feasible method to prioritise systems. The consultant had no connection with the organisation's systems and had to base his decisions on the brief descriptions accompanying each system.

The comparison matrix which resulted from the consultant's evaluation is given in Table 5.6 while the importance scale, derived from Table 5.6, is given as Table 5.7.

There was no obvious, easy way of telling whether the results had indicated that the correct method had been chosen. However, it was accepted as an appropriate technique for the specific circumstances due to the following:

- Inspection indicated that the technique has shown the important systems to be the expected important ones.

- Discussions with EDP personnel and certain users also indicated that the technique's evaluation corresponds with those systems felt intuitively to be the important systems.

Table 5.6 - Pair-wise System Comparison Matrix

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26
S1	1,00	6,00	0,20	0,20	9,00	0,25	0,33	0,25	0,25	0,20	5,00	5,00	4,00	0,50	0,50	0,50	5,00	1,00	1,00	5,00	5,00	5,00	5,00	5,00	5,00	1,00
S2	0,17	1,00	0,14	0,14	7,00	0,14	0,20	0,20	0,20	0,33	0,50	4,00	0,14	0,20	0,33	0,33	0,33	0,20	0,20	0,33	2,00	4,00	4,00	4,00	4,00	0,20
S3	5,00	7,00	1,00	3,00	9,00	0,33	1,00	1,00	1,00	4,00	5,00	5,00	5,00	4,00	3,00	3,00	5,00	3,00	3,00	5,00	6,00	7,00	7,00	7,00	7,00	1,00
S4	5,00	7,00	0,33	1,00	9,00	0,33	1,00	1,00	1,00	4,00	5,00	5,00	4,00	4,00	3,00	3,00	5,00	3,00	3,00	5,00	6,00	7,00	7,00	7,00	7,00	1,00
S5	0,11	0,14	0,11	0,11	1,00	0,11	0,11	0,11	0,11	0,11	0,11	1,00	0,11	0,11	0,14	0,11	0,25	0,11	0,11	0,25	0,20	0,20	0,20	0,20	0,20	0,11
S6	4,00	7,00	3,00	3,00	9,00	1,00	0,25	0,33	0,25	5,00	0,20	5,00	5,00	5,00	5,00	5,00	7,00	3,00	3,00	5,00	6,00	7,00	7,00	7,00	7,00	1,00
S7	3,00	5,00	1,00	1,00	9,00	4,00	1,00	0,33	0,25	5,00	5,00	5,00	3,00	5,00	5,00	5,00	7,00	3,00	3,00	5,00	6,00	7,00	7,00	7,00	7,00	1,00
S8	4,00	5,00	1,00	1,00	9,00	3,00	3,00	1,00	0,25	5,00	7,00	5,00	5,00	7,00	7,00	7,00	7,00	4,00	7,00	5,00	7,00	7,00	7,00	7,00	7,00	1,00
S9	4,00	5,00	1,00	1,00	9,00	4,00	4,00	4,00	1,00	5,00	7,00	5,00	5,00	7,00	7,00	7,00	7,00	7,00	7,00	5,00	7,00	7,00	7,00	7,00	7,00	1,00
S10	5,00	3,00	0,25	0,25	9,00	0,20	0,20	0,20	0,20	1,00	2,00	5,00	0,50	0,33	0,33	0,33	3,00	0,20	0,20	0,50	5,00	3,00	3,00	3,00	3,00	0,17
S11	0,20	2,00	0,20	0,20	9,00	5,00	0,20	0,14	0,14	0,50	1,00	4,00	0,25	0,33	0,33	0,33	5,00	0,20	0,20	1,00	5,00	5,00	5,00	5,00	5,00	1,00
S12	0,20	0,25	0,20	0,20	1,00	0,20	0,20	0,20	0,20	0,20	0,25	1,00	0,11	0,11	0,11	0,11	0,25	0,11	0,11	0,25	0,20	0,20	0,20	0,20	0,20	0,11
S13	0,25	7,00	0,20	0,25	9,00	0,20	0,33	0,20	0,20	2,00	4,00	9,00	1,00	0,50	2,00	2,00	6,00	0,25	0,25	5,00	6,00	7,00	7,00	7,00	7,00	1,00
S14	2,00	5,00	0,25	0,25	9,00	0,20	0,20	0,14	0,14	3,00	3,00	9,00	2,00	1,00	1,00	1,00	5,00	0,25	0,25	5,00	6,00	7,00	7,00	7,00	7,00	1,00
S15	2,00	3,00	0,33	0,33	7,00	0,20	0,20	0,14	0,14	3,00	3,00	9,00	0,50	1,00	1,00	0,25	5,00	0,25	0,25	5,00	6,00	7,00	7,00	7,00	7,00	1,00
S16	2,00	3,00	0,33	0,33	9,00	0,20	0,20	0,14	0,14	3,00	3,00	9,00	0,50	1,00	4,00	1,00	5,00	0,25	0,25	5,00	6,00	7,00	7,00	7,00	7,00	1,00
S17	0,20	3,00	0,20	0,20	4,00	0,14	0,14	0,14	0,14	0,33	0,20	4,00	0,17	0,20	0,20	0,20	1,00	0,20	0,20	0,50	0,50	0,50	0,50	0,50	0,50	0,17
S18	1,00	5,00	0,33	0,33	9,00	0,33	0,33	0,25	0,14	5,00	5,00	9,00	4,00	4,00	4,00	4,00	5,00	1,00	2,00	5,00	6,00	7,00	7,00	7,00	7,00	1,00
S19	1,00	5,00	0,33	0,33	9,00	0,33	0,33	0,14	0,14	5,00	5,00	9,00	4,00	4,00	4,00	4,00	5,00	0,50	1,00	5,00	6,00	7,00	7,00	7,00	7,00	1,00
S20	0,20	3,00	0,20	0,20	4,00	0,20	0,20	0,20	0,20	2,00	1,00	4,00	0,20	0,20	0,20	0,20	2,00	0,20	0,20	1,00	3,00	5,00	5,00	5,00	5,00	1,00
S21	0,20	0,50	0,17	0,17	5,00	0,17	0,17	0,14	0,14	0,20	0,20	5,00	0,17	0,17	0,17	0,17	2,00	0,17	0,17	0,33	1,00	2,00	2,00	2,00	2,00	0,25
S22	0,20	0,25	0,14	0,14	5,00	0,14	0,14	0,14	0,14	0,33	0,20	5,00	0,14	0,14	0,14	0,14	2,00	0,14	0,14	0,20	0,50	1,00	0,25	0,33	0,33	0,11
S23	0,20	0,25	0,14	0,14	5,00	0,14	0,14	0,14	0,14	0,33	0,20	5,00	0,14	0,14	0,14	0,14	2,00	0,14	0,14	0,20	0,50	4,00	1,00	0,33	0,33	0,11
S24	0,20	0,25	0,14	0,14	5,00	0,14	0,14	0,14	0,14	0,33	0,20	5,00	0,14	0,14	0,14	0,14	2,00	0,14	0,14	0,20	0,50	3,00	3,00	1,00	3,00	0,11
S25	0,20	0,25	0,14	0,14	5,00	0,14	0,14	0,14	0,14	0,33	0,20	5,00	0,14	0,14	0,14	0,14	2,00	0,14	0,14	0,20	0,50	3,00	3,00	0,33	1,00	0,11
S26	1,00	5,00	1,00	1,00	9,00	1,00	1,00	1,00	1,00	6,00	1,00	9,00	1,00	1,00	1,00	1,00	6,00	1,00	1,00	1,00	4,00	9,00	9,00	9,00	9,00	1,00

Table 5.7 - Importance Scale

SYSTEM	EIGENVECTOR	NORMALISED VALUE
1	0,1387	0,0355
2	0,0488	0,0125
3	0,3007	0,0769
4	0,2733	0,0699
5	0,0154	0,0039
6	0,3028	0,0774
7	0,3039	0,0777
8	0,3995	0,1021
9	0,4863	0,1243
10	0,0886	0,0226
11	0,1178	0,0301
12	0,0223	0,0057
13	0,1393	0,0356
14	0,1377	0,0352
15	0,1254	0,0321
16	0,1413	0,0361
17	0,0331	0,0085
18	0,2133	0,0545
19	0,2024	0,0517
20	0,0706	0,0180
21	0,0368	0,0094
22	0,0272	0,0070
23	0,0305	0,0078
24	0,0349	0,0089
25	0,0322	0,0082
26	0,1892	0,0484

It must be kept in mind that although the 26 systems in this exercise also form part of the 36 systems in the final rating, the numbers do not correspond. That is, for example, system number 1 in Table 5.7 is not the same system as system number 1 in the final evaluation, described later in this chapter. The reason for changing the order of the systems was to prevent old ratings from being used again, or influence new evaluations, without considering new information given to respondents, should a further round of testing be necessary.

Once this initial test had been completed the chosen thirty-six systems could be evaluated. It was decided, based on the view that importance was an in-house issue, not to make use of an outside consultant in the final prioritising exercise. A possibility exists that a consultant may give ratings based on experience gained from a totally different organisation in a completely different industry. This would mean that if, for example, the consultant regarded a Payroll system as very important he would possibly rate all Payroll systems as important without adequately considering other equally or more important systems in the specific organisation under review. Therefore, to keep the importance ratings specific to the organisation under review, it was necessary to exclude the consultant's ratings from the final exercise.

A senior EDP Manager was asked to do a pair-wise comparison of the systems. These results are given in Table 5.8. It was felt that this rating could contain "sympathy" ratings. This means that if the respondent had earlier worked as a team member on a system, e.g. payrolls, he would unintentionally rate the payroll system too high. To overcome this, a so-called "main" user was also asked to do a pair-wise comparison of the systems. The first evaluation could equally be used to counterbalance any possible bias ratings from the user. The results of the user are given in Table 5.9 and the average ratings, which were used in the final model, are given in Table 5.10.

Table 5.8 - Importance Scale (EDP Rating)

SYSTEM	EIGENVECTOR	NORMALISED VALUE
1	0,0174	0,0046
2	0,1416	0,0378
3	0,0543	0,0145
4	0,0245	0,0065
5	0,0226	0,0060
6	0,0744	0,0199
7	0,0208	0,0056
8	0,1279	0,0342
9	0,0171	0,0046
10	0,0563	0,0150
11	0,0584	0,0156
12	0,0664	0,0177
13	0,0309	0,0083
14	0,1325	0,0354
15	0,0355	0,0095
16	0,1747	0,0467
17	0,0088	0,0024
18	0,2874	0,0768
19	0,3682	0,0984
20	0,3682	0,0984
21	0,0146	0,0039
22	0,2565	0,0686
23	0,1391	0,0372
24	0,1610	0,0430
25	0,0702	0,0188
26	0,2456	0,0656
27	0,0787	0,0210
28	0,0146	0,0039
29	0,0706	0,0189
30	0,0578	0,0154
31	0,2276	0,0608
32	0,2276	0,0608
33	0,0161	0,0043
34	0,0489	0,0131
35	0,0147	0,0039
36	0,0110	0,0029

Table 5.9 - Importance Scale (User Rating)

SYSTEM	EIGENVECTOR	NORMALISED VALUE
1	0,0112	0,0028
2	0,0639	0,0158
3	0,0152	0,0037
4	0,0152	0,0037
5	0,0152	0,0037
6	0,0152	0,0037
7	0,0152	0,0037
8	0,0188	0,0047
9	0,0496	0,0123
10	0,0492	0,0122
11	0,0803	0,0199
12	0,0801	0,0198
13	0,0790	0,0196
14	0,2289	0,0566
15	0,0637	0,0158
16	0,2836	0,0702
17	0,0286	0,0071
18	0,1296	0,0321
19	0,5509	0,1363
20	0,4345	0,1075
21	0,1142	0,0283
22	0,3362	0,0832
23	0,1376	0,0341
24	0,2737	0,0677
25	0,0566	0,0140
26	0,0800	0,0198
27	0,0561	0,0139
28	0,0660	0,0163
29	0,1696	0,0420
30	0,1297	0,0321
31	0,1280	0,0317
32	0,1219	0,0302
33	0,0215	0,0053
34	0,0736	0,0182
35	0,0241	0,0060
36	0,0241	0,0060

Table 5.10 - Average Importance Scale used in Final Model

SYSTEM	EIGENVECTOR	NORMALISED VALUE
1	0,0143	0,0037
2	0,1028	0,0264
3	0,0348	0,0089
4	0,0199	0,0051
5	0,0189	0,0049
6	0,0448	0,0115
7	0,0180	0,0046
8	0,0734	0,0189
9	0,0334	0,0086
10	0,0528	0,0136
11	0,0694	0,0178
12	0,0733	0,0188
13	0,0550	0,0141
14	0,1807	0,0464
15	0,0496	0,0127
16	0,2292	0,0589
17	0,0187	0,0048
18	0,2085	0,0536
19	0,4596	0,1181
20	0,4014	0,1031
21	0,0644	0,0165
22	0,2964	0,0762
23	0,1384	0,0356
24	0,2174	0,0558
25	0,0634	0,0163
26	0,1628	0,0418
27	0,0674	0,0173
28	0,0403	0,0104
29	0,1201	0,0309
30	0,0938	0,0241
31	0,1778	0,0457
32	0,1748	0,0449
33	0,0188	0,0048
34	0,0613	0,0157
35	0,0194	0,0050
36	0,0176	0,0045

5.5 FINAL RESULTS

The final results obtained from analysing the data pertaining to risk, success and importance of computerised systems are given in Table 5.11. These figures were used in the final model to allocate resources discussed in Chapter 7.

Table 5.11

SYSTEM	RISK	SUCCESS	IMPORTANCE
1	3,5	5	0,0037
2	3,5	6	0,0264
3	2,5	6	0,0089
4	2,0	6	0,0051
5	2,5	5	0,0049
6	1,5	6	0,0115
7	2,0	4	0,0046
8	2,0	6	0,0189
9	3,0	6	0,0086
10	2,0	4	0,0136
11	2,0	6	0,0178
12	3,0	5	0,0188
13	2,5	6	0,0141
14	3,0	6	0,0464
15	3,0	3	0,0127
16	3,0	5	0,0589
17	3,0	4	0,0048
18	4,0	5	0,0536
19	3,5	6	0,1181
20	3,5	6	0,1031
21	1,5	4	0,0165
22	3,5	5	0,0762
23	2,5	5	0,0356
24	2,0	7	0,0558
25	3,0	6	0,0163
26	2,5	7	0,0418
27	2,0	5	0,0173
28	3,0	4	0,0104

Table 5.11 (Continued)

SYSTEM	RISK	SUCCESS	IMPORTANCE
29	2,5	5	0,0309
30	3,5	5	0,0241
31	5,5	3	0,0457
32	4,0	5	0,0449
33	3,5	2	0,0048
34	3,5	5	0,0157
35	3,0	4	0,0050
36	2,0	5	0,0045

5.6 SUMMARY

The data obtained in the research project were analysed and investigated in this chapter. It resulted in two regression models, for risk and success, which form the basis for the optimisation models which will be discussed in the next chapter. A technique for prioritising systems was tested with the input from an independent consultant and eventually resulted in a complete importance scale for the chosen systems. Chapter 4 concluded with a table of final results pertaining to risk, success and importance for each system, which will be used in the final model to allocate resources.

CHAPTER 6

OPTIMISATION TECHNIQUES APPLIED TO THE LINEAR REGRESSION MODELS

6.1 INTRODUCTION

Linear regression models regarding the risk and success of computerised systems will be used in this chapter to try and find improvement strategies for the dependent variables, R(Risk) and S(Success), by adjusting the decision variables. The LP procedure provided by the SAS System and described in Chapter 4 was used in this calculation.

6.2 FORMULATION OF THE MODELS

Application of the technique by *Bruwer and Hattingh* and discussed in Chapter 4 involves the formulation of linear programming problems with objective functions and constraints as set out in Paragraphs 6.2.1 and 6.2.2. As explained in [7] this technique is aimed at the interpretation of linear models that have been obtained by investigating the behaviour of the objective function over the region of experience as defined by the convex hull of the data points.

Researchers are usually interested in the influence of independent variables on the dependent variable. As already explained in Chapter 4, this study is also concerned with this issue, as well as with the problem of interdependency among the independent variables. The technique used provides a method of investigating these inter-dependencies to enable us to find improvement strategies (or strategies to be avoided) regarding factors influencing computerised systems.

6.2.1 Risk Model

The model can be formulated as:

MAX

$$R = b_0 + b_1 X_1 + \ldots + b_k X_k$$

MIN

subject to:

$$\lambda_1 X_{11} + \lambda_2 X_{21} + \ldots + \lambda_n X_{n1} - X_1 = 0$$

$$\lambda_1 X_{12} + \lambda_2 X_{22} + \ldots + \lambda_n X_{n2} - X_2 = 0$$

.

.

.

$$\lambda_1 X_{1k} + \lambda_2 X_{2k} + \ldots + \lambda_n X_{nk} - X_k = 0$$

$$X_p = q \quad (q=1, 2, \ldots, 7) \tag{6.1}$$

$$\lambda_1 + \lambda_2 + \ldots + \lambda_n = 1$$

$$\lambda_1, \lambda_2, \ldots, \lambda_n \geq 0$$

where X_{ij} denotes the i-th measurement on variable X_j. R denotes the Risk to be minimised (if maximised, to find strategies which should be avoided).

$X_1, X_2, \ldots, X_k$ unlimited in sign where $k = 6$ and $n = 36$

The variables are:

X_1 = OldRisk; X_2 = F1; X_3 = F2;

$X_4 = F_4$; X_5 = F5; $X_6 = F_6$

Furthermore,

$b_0 = 3{,}3961$; $b_1 = 0{,}3440$; $b_2 = -0{,}1018$; $b_3 = -0{,}1345$; $b_4 = 0{,}1976$; $b_5 = -0{,}1869$; $b_6 = -0{,}1316$

as obtained from the Risk regression equation found in Chapter 5.

Should it be necessary to solve this linear program with X_1, X_2, ..., X_k unlimited in sign by the simplex method, it would be necessary to perform a transformation on these variables to obtain a model with non-negative variables. Such a method is described in *Dantzig* [20]. The formulation of the LP will then have to change but in this specific case all X's have positive coefficients (all data were positive) and the sum of the λ's is restricted to 1. This will imply that solutions that satisfy the constraints will necessarily be non-negative.

6.2.1.1 Optimisation of the model

The optimisation was carried out as follows:

Each one of the independent variables was substituted, in turn, in the constraint equation 6.1. This means that p was set sequentially to the values 1, 2, ..., 6. For each of the variables, R was maximised and minimised where $q=1$ initially. q was then incremented by 1 until $q=7$ and for each of these q-values the maximum and minimum for R were calculated using the LP procedure provided by the SAS-System. Parametric programming could be used but was unnecessary as all data points were obtained from a 7-point scale. Solutions were only needed when decision variables were on one of the 7 levels and therefore parametric programming, which in general could give solutions for the whole range of q-values, was not used in this specific case.

This procedure resulted in 14 linear programming problems for each of the decision variables used in 6.1. Results of these linear programming problems were then used as input to QUATTRO PRO to produce a graphic representation of the maximum and minimum values when the decision variables in 6.1 were restricted to 1, 2, ..., 7.

It is possible that no feasible solution exists when a decision variable is restricted to a certain level if such a specific combination did not occur in the convex hull. This also happens when no data points on this specific level for this specific decision variable were obtained from the questionnaires.

6.2.1.2 Discussion of results

The results are given in the form of graphic representations in Figures 6.1 to 6.6.

When looking at the total area, as indicated on the graphs, the following could be seen:

A decision variable, restricted to a certain level, determines the minimum of the risk (R) on that level as well as the maximum of *R* on that level. Other feasible solutions may exist between those two optimum values.

The difference between the maximum and minimum value of *R*, at any level (1, 2, ..., 7) of the decision variable, gives an indication of the impact the remaining decision variables would have on *R*. If the difference is small then the remaining decision variables would have little influence on *R*. Likewise, the difference would be big should the remaining decision variables have a big impact on *R*. Therefore, the smaller the 'band' (given by the total area on the graphic representation), the smaller the influence of the other remaining decision variables. The areas on each graph are divided in two by the mean value of *R*.

<u>X_1 - Profile risk based on state variables</u>

Figure 6.1 is the graphic representation of all optimal risk values when the variable X_1 is restricted to 1, 2, ..., 7. The results on the graph clearly indicate that this variable X_1 (profile risk based on state variables) will have an impact

on the risk of a computerised system. This can be seen from the fact that the graph, formed by joining the maximum values, is non-decreasing. This is also true for the graph that joins the minimum values. When this variable is high (say at level 6), the optimum value for the dependent variable *R* is also at its highest.

The interpretation that can be given to this graph (Figure 6.1) is that at high values of X_1 (Profile Risk) it is difficult to select values of decision variables that will result in low risk situations. The tables above and below Figure 6.1 give suggestions as to the levels of the decision variables that can be employed to find higher expected Risk (or what strategies not to follow) or lower expected Risk. If X_1 is at level 6, it thus seems a good idea to have X_4 (Recent Changes to System or Key Personnel) at a low level, X_5 (Management Involvement) at a high level, etc. Similar interpretations can be given to other levels of X_1.

Note that the optimisation will not suggest values of the variables not contained in the convex hull of the data points.

According to *Bruwer* [5] the mean optimum values, at maximum and minimum R-values, provides a quick and easy method of observing the influence of remaining variables in the model. Table 6.1 provides the mean optimum values for the remaining different variables at the minimum and maximum R-values.

Table 6.1

VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
X_2	5,20	6,64
X_3	4,30	4,70
* X_4	5,35	1,00
* X_5	1,95	5,76
X_6	4,30	5,60

* Highest difference between optimum values

Physical security (X_2), when X_1 is restricted to 1, 2, ..., 7:

It is clear from the mean values in Table 6.1 that physical security does have an influence on the risk of computer systems. Although not much, the physical security has to be adjusted to minimise the risk.

Technology used (X_3), when X_1 is restricted to 1, 2, ..., 7:

Technology used, on average, has very little influence on the risk of systems.

Recent changes to system or key personnel (X_4), when X_1 is restricted to 1, 2, ..., 7:

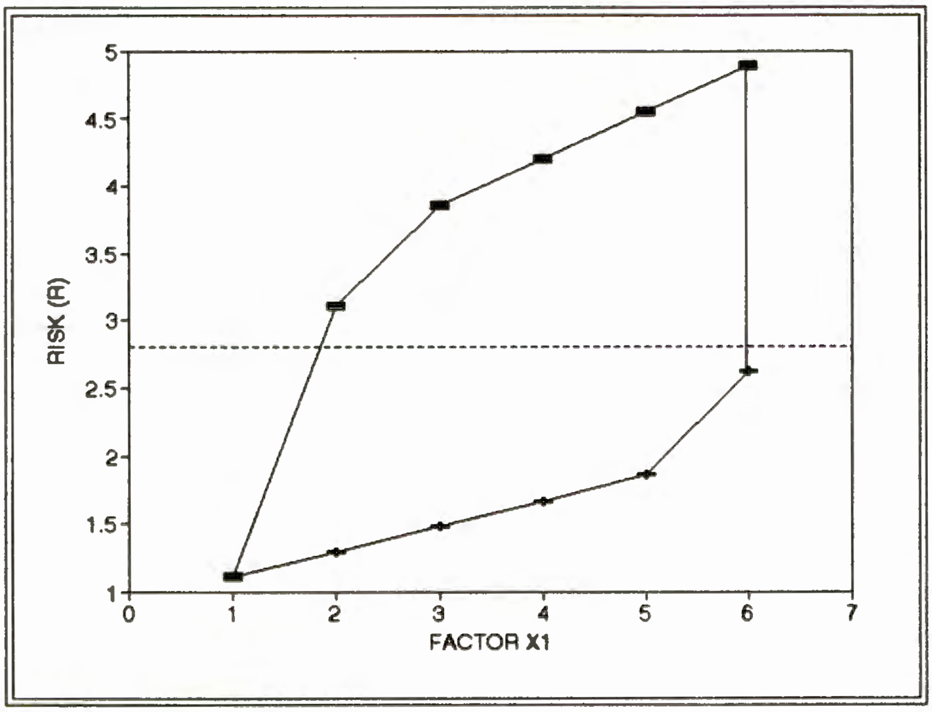
It appears as if this factor has a major impact on the risk. As the maximum risk increased, this factor also increased. Furthermore, it has the biggest difference between the mean optimum values (Table 6.1) which is an indication of how changes to the system and key personnel should be restricted in order to minimise risk.

Figure 6.1

Maximum and Minimum *R*-Values for Variable X_1

(Profile Risk Based on State Variables)

MAXIMUM							
X1	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X2	6.00	5.20	5.00	5.00	5.00	5.00	
X3	6.00	3.60	3.35	3.82	4.29	4.76	
X4	1.00	5.00	6.18	6.41	6.65	6.88	
X5	4.00	1.60	1.18	1.41	1.65	1.88	
X6	5.00	5.00	4.65	4.18	3.71	3.24	
R(MAX)	1.11	3.10	3.86	4.20	4.55	4.89	



MINIMUM							
X1	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X2	6.00	6.31	6.62	6.92	7.00	7.00	
X3	6.00	5.38	4.77	4.15	4.00	4.00	
X4	1.00	1.00	1.00	1.00	1.00	1.00	
X5	4.00	4.92	5.65	6.77	7.00	6.00	
X6	5.00	5.31	5.62	5.92	6.75	5.00	
R(MIN)	1.11	1.30	1.48	1.66	1.87	2.63	

How managers (EDP and Users) act, e.g. support, attitude, etc (X_5), when X_1 is restricted to 1, 2, ..., 7:
As with factor X_4 this factor plays a major role in the model. The different X_5-values need to be kept at high levels to minimise *R*. Table 6.1 also indicates a big difference between the optimum values which in turn means a major adjustment to this factor in order to deal with the risk of a system.

Communication between DP Department and Users (X_6) when X_1 is restricted to 1, 2, ..., 7:
Although not much, communication does have an impact on the risk of systems as indicated by the mean optimum values in Table 6.1. All the individual values of X_6 are high when minimising risk.

It could be concluded from the graph, accompanying variable values and the above discussion that factors X_4 and X_5 are the major ones which will have to be adjusted when trying to minimise risk.

<u>X_2 - Physical security</u>
The same analysis, as for X_1, can be applied to the impact of higher and lower values of X_2 on the expected risk. However, it must be borne in mind that X_2 can be considered to be a decision variable whereas X_1 was a state variable.

The graphic representation of all optimal values, when the variable X_2 is restricted to 1, 2, ..., 7, is given in Figure 6.2. Note how the maximum risk increased and minimum risk decreased at levels 3, 4 and 5, while the opposite is true for levels 6 and 7. The impact of the other variables is at the their highest when the minimum risk is low (levels 5 and 6).

Table 6.2

VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
* X_1	5,30	2,40
X_3	4,70	3,60
X_4	3,40	1,60
X_5	3,20	5,20
X_6	3,00	5,20

* Highest difference between optimum values

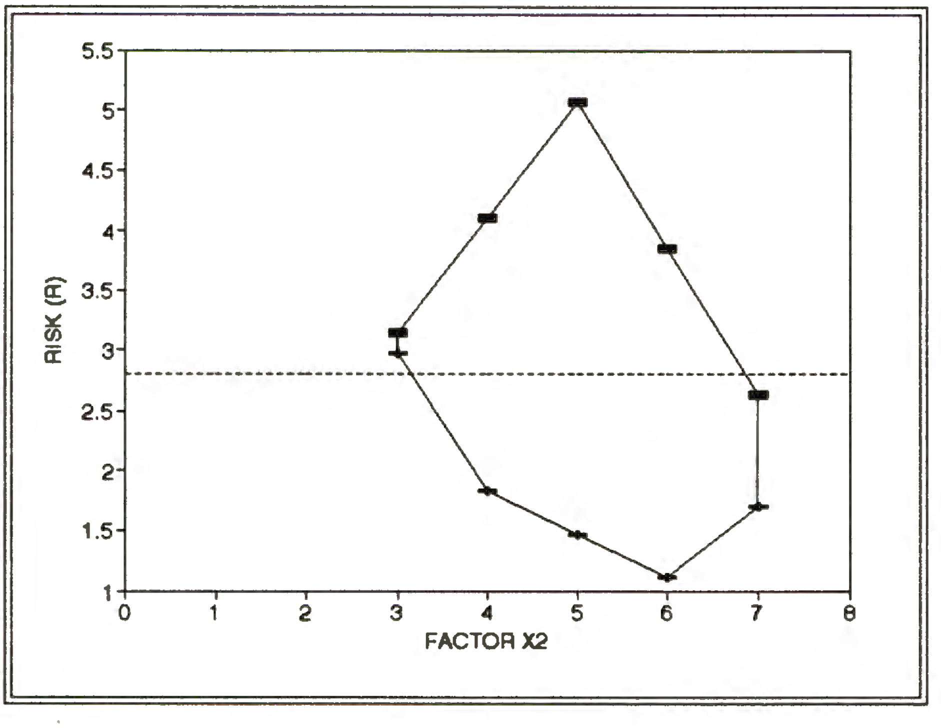
Profile risk based on state variables (X_1), when X_2 is restricted to 1, 2, ..., 7: Table 6.2 indicates that this variable has the highest difference between optimum values, which is clearly an indication of the major role it will play in the risk of a system. Unfortunately, variable X_1 is regarded as a state variable which would be difficult or impossible to change.

Technology used (X_3), when X_2 is restricted to 1, 2, ..., 7:
The technology used has little influence on the risk. It is obvious from the given X_3-values that when the maximum risk increases (levels 3, 4 and 5) that the X_3-value remains on 5. When the maximum risk decreases there is only a 0,5 change in the X_3-values. This variable also has the lowest difference between its mean optimum values.

Figure 6.2

Maximum and Minimum R Values for Variable X_2 (Physical Security)

MAXIMUM X2	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1			3.00	4.75	6.50	6.25	6.00
X3			5.00	5.00	5.00	4.50	4.00
X4			1.00	4.00	7.00	4.00	1.00
X5			2.00	2.00	2.00	4.00	6.00
X6			1.00	2.00	3.00	4.00	5.00
R(MAX)			3.14	4.10	5.07	3.85	2.63



MINIMUM X2	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1			2.25	2.00	1.50	1.00	4.25
X3			2.00	2.00	4.00	6.00	4.00
X4			4.00	1.00	1.00	1.00	1.00
X5			4.00	6.00	5.00	4.00	7.00
X6			5.00	5.00	5.00	5.00	6.00
R(MIN)			2.98	1.83	1.47	1.11	1.71

Recent changes to system or key personnel (X_4), when X_2 is restricted to 1, 2, ..., 7:
Although not a big difference in mean optimum values, X_4 certainly is a role player in the risk of a system. Note that the X_4-values increase (1, 4, 7) when the maximum risk increase (levels, 3, 4 and 5). As soon as the maximum risk decreases (levels 6 and 7), the X_4-values also decrease to 4 and 1 respectively. A mean optimum value of 1,60 for minimum risk also indicates that X_4 should be kept at low levels to minimise risk.

How managers (EDP and users) act, e.g. support, attitude, etc. (X_5), when X_2 is restricted to 1, 2, ..., 7:
The same applies to X_5 as for X_4. Note especially that when the maximum risk decreases at levels 6 and 7, the X_5 value increased from 2 to 4 and from 4 to 6. This could be a strong indication of how important management involvement is. The optimum X_5-values for the minimised risk are constantly high.

Communication between DP Department and users (X_6), when X_2 is restricted to 1, 2, ..., 7:
Although the two X_6-values at levels 6 and 7 for maximum risk are contradictory, the constantly high optimum X_6-values for minimised risk indicates that sufficient communication between the DP Department and users is essential to keep risk levels as low as possible.

In conclusion, this analysis indicates that X_1 should be the most important variable to adjust when trying to control risk. However, X_1 is a state variable and cannot be (easily) adjusted. X_4, X_5 and X_6 all had a fair amount of influence on the risk of a system with X_5 possibly the strongest factor among them.

X_3 - Technology used

Figure 6.3 shows that the restriction of X_3 to the values 1, 2, ..., 7 closely resembles the previous case of variable X_2 - Physical Security. The impact on the maximum/minimum risk of other variables is high, as indicated by the broad 'band' on the graph between maximum and minimum risk values.

Table 6.3

VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
* X_1	6,02	2,13
X_2	5,58	5,17
* X_4	6,33	2,00
X_5	3,75	5,00
X_6	4,75	6,00

* Highest difference between optimum values

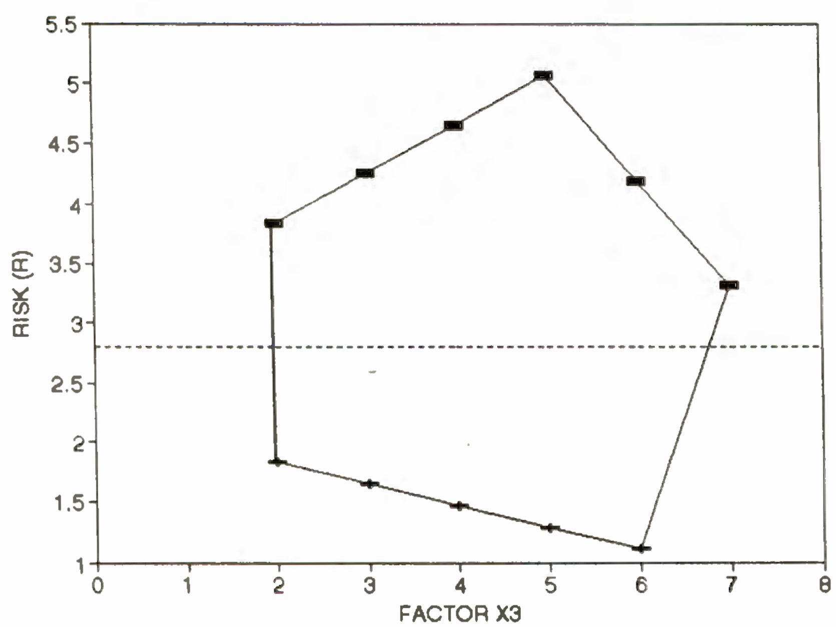
The variable X_1 (Profile risk based on the state variables) has a significant difference in optimum values and appear to have a major impact. However, it is regarded as a state variable and cannot be changed.

Physical security (X_2), when X_3 is restricted to 1, 2, ..., 7:
The difference between the mean optimum values indicates that this factor does not play a major role in this case.

Figure 6.3

Maximum and Minimum R Values for Variable X_3 (Technology Used)

MAXIMUM X3	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1		6.00	6.17	6.33	6.50	5.88	5.25
X2		6.00	5.67	5.33	5.00	5.50	6.00
X4		5.00	5.67	6.33	7.00	7.00	7.00
X5		5.00	4.00	3.00	2.00	3.50	5.00
X6		6.00	5.00	4.00	3.00	4.50	6.00
R(MAX)		3.84	4.25	4.66	5.07	4.19	3.31



MINIMUM X3	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1		2.00	1.75	1.50	1.25	1.00	5.25
X2		4.00	4.50	5.00	5.50	6.00	6.00
X4		1.00	1.00	1.00	1.00	1.00	7.00
X5		6.00	5.50	5.00	4.50	4.00	5.00
X6		5.00	5.00	5.00	5.00	5.00	6.00
R(MIN)		1.83	1.65	1.47	1.29	1.11	3.31

Recent changes to system or key personnel (X_4), when X_3 is restricted to 1, 2, ..., 7:
A difference of 4,33 in mean optimum values is an indication of the major role that X_4 plays in determining risk of a system. At the different minimum risk values X_4 remains at a level of 1 except for the last value which is 7 because the minimum risk increased from 1,11 (level 6) to 3,31 (level 7). Remaining at a level of 1 clearly shows that recent changes to systems or key personnel should be limited as far as possible.

How managers (EDP and users) act e.g. support, attitude, etc. (X_5), when X_3 is restricted to 1, 2, ..., 7:
The optimum values for X_5 correspond with the maximum and minimum risk as indicated on the graph. As management involvement decreases (level 2, 3, 4 and 5), maximum risk increases. A decrease in maximum risk (levels 6 and 7) corresponds with the increase in management involvement. The same applies to the X_5-values and corresponding minimum risk values. It therefore appears that X_5 does have an influence on the risk of a system.

Communication between DP Department and users (X_6), when X_3 is restricted to 1, 2, ..., 7:
The given optimum X_6-values show that X_6 will also have a significant impact on the risk of a system.

X_4, X_5 and X_6, with X_4 the major role player, will all have a significant impact on determining maximum and minimum risk levels of different computerised systems.

X_4 - Recent changes to system or key personnel

It is clear from Figure 6.4 that recent changes to a system or key personnel are very important in determining risk levels. A sharp increase in both the maximum and minimum risk values can be seen on the graph when the level of X_4 is increased.

Table 6.4

VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
X_1	4,75	3,13
X_2	4,00	6,00
X_3	5,00	6,50
* X_5	2,00	4,50
* X_6	2,00	5,50

* Highest difference between optimum values

Profile risk based on state variable (X_4) - state variable and cannot be changed.

Physical security (X_2), when X_4 is restricted to 1, 2, ..., 7:

Physical security does have an effect on the risk as indicated by the increasing X_2-values when maximum risk increases.

Technology used (X_3), when X_4 is restricted to 1, 2, ..., 7:

Technology used would have no major impact in this case as it is indicated by the given X_3-values as well as the relatively small difference in mean optimum values.

How managers (EDP and users) act, e.g., support, attitude, etc. (X_5), when X_4 is restricted to 1, 2, ..., 7:
The difference between the mean optimum values showed that managers' involvement would play a significant role.

Communication between DP Department and users (X_6), when X_4 is restricted to 1, 2, ..., 7:
As with management involvement, communication proves to be very important when determining risk levels. X_6 has the biggest difference between its mean optimum values.

Variables X_5, X_6 and to a lesser extent, X_2, are the important factors, in this case, to adjust in order to change the risk levels of a system.

X_5 - How managers (EDP and users) act e.g., support, attitude, etc.
The graphic representation when varying the level of X_5 is given in Figure 6.5. It can be seen from the graph that this factor also has a significant impact on the risk levels, e.g. the higher the level of management involvement the lower the corresponding maximum risk level. The remaining factors would have a significant impact on the risk levels as indicated by the broad 'band' on the graph.

Table 6.5

VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
* X_1	5,61	2,29
X_2	5,79	6,00
X_3	4,36	4,57
* X_4	5,14	2,57
X_6	4,29	5,29

* Highest difference between optimum values

Profile risk based on state variables (X_1) - state variable and cannot be changed.

Physical security (X_2), when X_5 is restricted to 1, 2, ..., 7:
This factor does not play a major role in this case and its optimum values stay nearly the same for all levels of X_5.

Technology used (X_3), when X_5 is restricted to 1, 2, ..., 7:
Although there is a very small difference in the mean optimum values of X_3, the different X_3-values tend to follow the maximum and minimum risk values. This in turn may be an indication of the influence of technology used.

Recent changes to system or key personnel (X_4), when X_5 is restricted to 1, 2, ..., 7:
X_4 has the highest difference in mean optimum values (except for the state variable X_1) which is an indication of the importance of this factor. A close look at the different X_4 optimum values when risk is maximised shows that they correspond with the risk values. When risk is minimised, X_4 decreased to 1 and then remains at the low level of 1. This clearly proves that, in order to keep risk at a low level, changes to systems or key personnel should be limited.

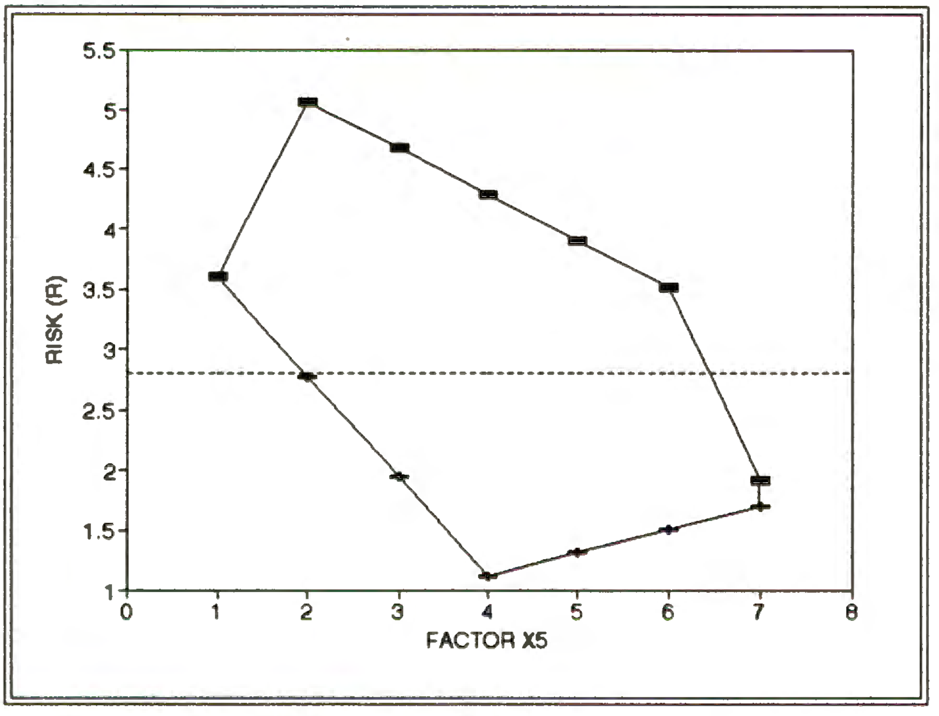
Communication between DP Department and users (X_6), when X_5 is restricted to 1, 2, ..., 7:
As with X_4, the X_5-values increase when maximum risk decreases, while they are constantly at high levels when risk is minimised. Communication between DP Department and Users should therefore also be regarded as an important factor influencing the risk of a computerised system.

The important factors, for the case where X_5 is restricted to the 7 different levels, appear to be X_4 and X_6.

Figure 6.5

Maximum and Minimum *R* Values for Variable X_5 (How Managers (EDP and users) act)

MAXIMUM X5	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1	2.75	6.50	6.38	6.25	6.13	6.00	5.25
X2	6.00	5.00	5.25	5.50	5.75	6.00	7.00
X3	4.00	5.00	4.75	4.50	4.25	4.00	4.00
X4	5.00	7.00	6.50	6.00	5.50	5.00	1.00
X6	3.00	3.00	3.50	4.00	4.50	5.00	7.00
R(MAX)	3.60	5.07	4.68	4.29	3.91	3.52	1.92



MINIMUM X5	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1	2.25	1.83	1.42	1.00	2.08	3.17	4.25
X2	5.00	5.33	5.67	6.00	6.33	6.67	7.00
X3	3.00	4.00	5.00	6.00	5.33	4.67	4.00
X4	6.00	4.33	3.67	1.00	1.00	1.00	1.00
X6	5.00	5.00	5.00	5.00	5.33	5.67	6.00
R(MIN)	3.60	2.77	1.94	1.11	1.31	1.51	1.71

Profile risk based on state variables (X_1) - state variable and cannot be changed.

Physical security (X_2), when X_5 is restricted to 1, 2, ..., 7:
This factor does not play a major role in this case and its optimum values stay nearly the same for all levels of X_5.

Technology used (X_3), when X_5 is restricted to 1, 2, ..., 7:
Although there is a very small difference in the mean optimum values of X_3, the different X_3-values tend to follow the maximum and minimum risk values. This in turn may be an indication of the influence of technology used.

Recent changes to system or key personnel (X_4), when X_5 is restricted to 1, 2, ..., 7:
X_4 has the highest difference in mean optimum values (except for the state variable X_1) which is an indication of the importance of this factor. A close look at the different X_4 optimum values when risk is maximised shows that they correspond with the risk values. When risk is minimised, X_4 decreased to 1 and then remains at the low level of 1. This clearly proves that, in order to keep risk at a low level, changes to systems or key personnel should be limited.

Communication between DP Department and users (X_6), when X_5 is restricted to 1, 2, ..., 7:
As with X_4, the X_5-values increase when maximum risk decreases, while they are constantly at high levels when risk is minimised. Communication between DP Department and Users should therefore also be regarded as an important factor influencing the risk of a computerised system.

The important factors, for the case where X_5 is restricted to the 7 different levels, appear to be X_4 and X_6.

X_6 - Communication between DP Department and users

The graphic representation (Figure 6.6) for variable X_6 shows that the influence of X_6 is almost the same as in the previous case for X_5.

Table 6.6

VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
X_1	5,50	2,63
X_2	5,00	5,57
X_3	4,00	4,79
* X_4	4,86	1,00
X_5	4,00	4,21

* Highest difference between optimum values

Profile risk based on state variables (X_1) - state variable and cannot be changed.

Physical security (X_2), when X_6 is restricted to 1, 2, ..., 7:

From the optimum values it can be seen that this factor needs to be kept at high levels to minimise risk. However, the factor X_2 does not play a major role in this case.

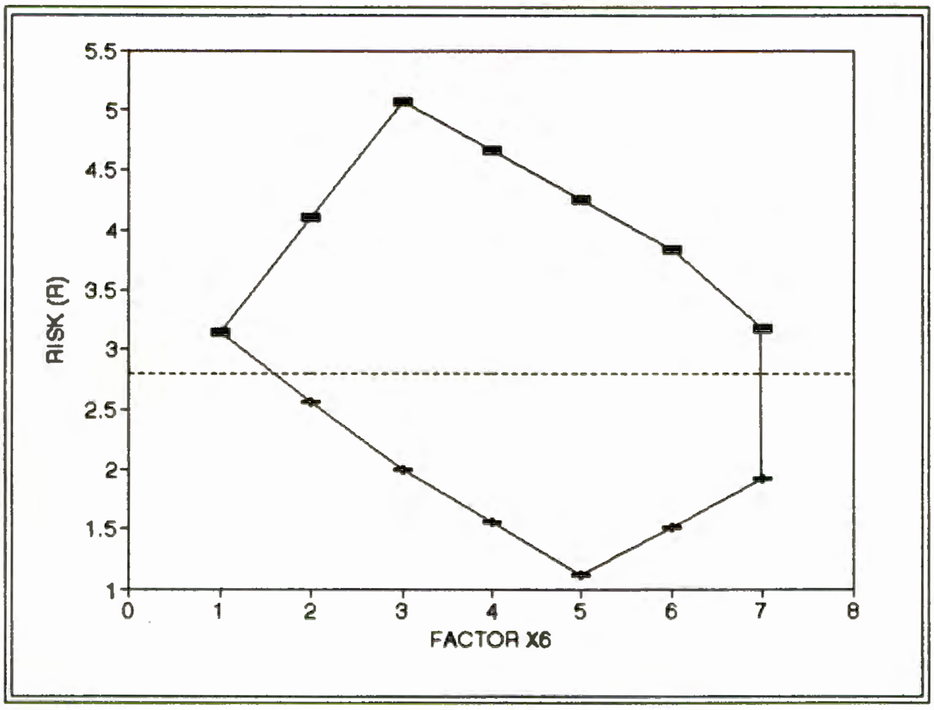
Technology used (X_3), when X_6 is restricted to 1, 2, ..., 7:

It would be safe to assume that the technology used does not have a major impact, as can be seen from the small difference between its mean optimum values.

Figure 6.6

Maximum and Minimum *R* Values for Variable X_6 (Communication between DP Department and users)

MAXIMUM X6	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1	3.00	4.75	6.50	6.33	6.17	6.00	5.75
X2	3.00	4.00	5.00	5.33	5.67	6.00	6.00
X3	5.00	5.00	5.00	4.00	3.00	2.00	4.00
X4	1.00	4.00	7.00	6.33	5.67	5.00	5.00
X5	2.00	2.00	2.00	3.00	4.00	5.00	6.00
R(MAX)	3.14	4.10	5.07	4.66	4.25	3.84	3.17



MINIMUM X6	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1	3.00	2.50	2.00	1.50	1.00	3.13	5.25
X2	3.00	4.50	6.00	6.00	6.00	6.50	7.00
X3	5.00	4.50	4.00	5.00	6.00	5.00	4.00
X4	1.00	1.00	1.00	1.00	1.00	1.00	1.00
X5	2.00	3.00	4.00	4.00	4.00	5.50	7.00
R(MIN)	3.14	2.57	1.99	1.55	1.11	1.52	1.92

Recent changes to system or key personnel (X_4), when X_6 is restricted to 1, 2, ..., 7:

X_4 is a major role player in determining risk levels. This is proved by the very high difference in mean optimum values in Table 6.6. The optimum X_4-values, when minimising risk, remain low at 1. This proves, as in the previous case where X_5 was limited to different levels, that in order to keep risk as low as possible, changes to systems or key personnel should be limited.

How managers (EDP and users) act, e.g., support, attitude, etc. (X_5), when X_6 is restricted to 1, 2, ..., 7:

Table 6.6 shows a very small difference between the X_5 mean optimum values. However, inspection of the individual X_5-values show that these values correspond to the maximum and minimum risk values. This in turn may be an indication of the extent of influence management involvement has on the risk levels.

It appears that in this case, where X_6 is varying from 1 to 7, the major factor to be adjusted, in order to change the risk level, would be factor X_4 - recent changes to system or key personnel.

6.2.1.3 Conclusion

The graphs presented in Figures 6.1 to 6.6, and the accompanying optimum values for each variable, showed that the risk of a system could be changed by changing the different factors. A "satisfactory" regression model was constructed consisting of various "independent" variables. Application of the optimisation technique then indicated which variables are the most important ones to be adjusted. The optimum values also indicated how they should be adjusted to reduce the risk of a computer system optimal. The following three factors proved to be the major variables to be changed in order to adjust the risk levels:

X_4 - Recent changes to system or key personnel
X_5 - How managers (EDP and Users) act, e.g., support, attitude, etc.
X_6 - Communication between DP Department and users

In practice it may be necessary to investigate the effect when more than one variable is limited to a certain level. This was not done as part of the research project; however, a completely worked out example of such a model can be found in [5].

6.2.2 Success model

The same methodology, as described for the Risk Model (6.2.1) can be applied to the Success model.

The model can be formulated as:

$$\begin{matrix} \text{MAX} \\ \text{MIN} \end{matrix} \quad S = b_0 + b_1X_1 + \ldots + b_kX_k$$

Subject to:

$$\lambda_1X_{11} + \lambda_2X_{21} + \ldots + \lambda_nX_{n1} - X_1 = 0$$
$$\lambda_1X_{12} + \lambda_2X_{22} + \ldots + \lambda_nX_{n2} - X_2 = 0$$
$$\vdots$$
$$\lambda_1X_{1k} + \lambda_2X_{2k} + \ldots + \lambda_nX_{nk} - X_k = 0$$
$$X_p = q \quad (q = 1, 2 \ldots, 7)$$

$$\lambda_1 + \lambda_2 + \ldots + \lambda_n = 1$$
$$\lambda_1, \lambda_2, \ldots, \lambda_n \geq 0$$

where X_{ij} denotes the i-th measurement on variable X_j. S denotes the success to be maximised (if minimised to find strategies which should be avoided).

$X_1, X_2, \ldots, X_k$ unlimited in sign where $k = 6$ and $n = 36$

The variables are:
$X_1 = F_1$; $X_2 = F_4$; $X_3 = F_5$;
$X_4 = F_6$; $X_5 = F_7$; $X_6 = F_8$
Furthermore,
$b_0 = 0{,}9926$; $b_1 = 0{,}1464$; $b_2 = 0{,}1536$; $b_3 = 0{,}1163$; $b_4 = 0{,}1305$; $b_5 = 0{,}1595$; $b_6 = 0{,}1583$
as obtained from the Success regression equation found in Chapter 5.

This linear programming problem is exactly the same as the one given for risk in Paragraph 6.1.1. It is only the constant values, $b_0, b_1, \ldots, b_6$, and the independent variable, S, that have changed. This, together with the fact that the same optimisation technique, as with the risk model, will be applied to the problem, means that all the assumptions and explanations which were given for the risk model will be applicable to the Success model.

6.2.2.1 Discussion of results

The results are given in the form of graphic representation in Figures 6.7 to 6.12.

The results for the risk model were discussed in full. The same reasoning can be followed to interpret the graphs for the Success model. Each factor, influencing success will therefore not be discussed as comprehensively as the risk factors.

X_1 - Top management involvement

Figure 6.7 is the graphic representation of all optimal success values when the variable X_1 is restricted to 1, 2, ..., 7.

The ascending curves for both maximum and minimum success values clearly indicate that an increase in top management involvement will increase the success level of computer systems. The broad 'band' between maximum and minimum values means that other variables also have a considerable amount of influence on the success levels. This is also clear from Table 6.7 where the mean maximum and minimum optimum values are given. All variables showed a significant difference between the mean optimum values with X_3 and X_6 possibly the strongest role players.

Table 6.7

VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
X_2	6,00	2,93
* X_3	6,50	3,07
X_4	6,00	2,79
X_5	5,86	2,79
* X_6	6,50	2,73

* Highest difference between optimum values

X_2 - EDP Centre/Function

Factor X_2, as represented on the graph in Figure 6.8, also shows that a significant improvement in success is possible by adjusting this variable.

Variables X_1 and X_4 appeared to have the most significant impact as they are the ones with the highest differences in optimum values. It is also interesting to note that at low success levels (X_2 = 2 and 3) the other remaining variables do not have a big influence on the success level.

Table 6.8

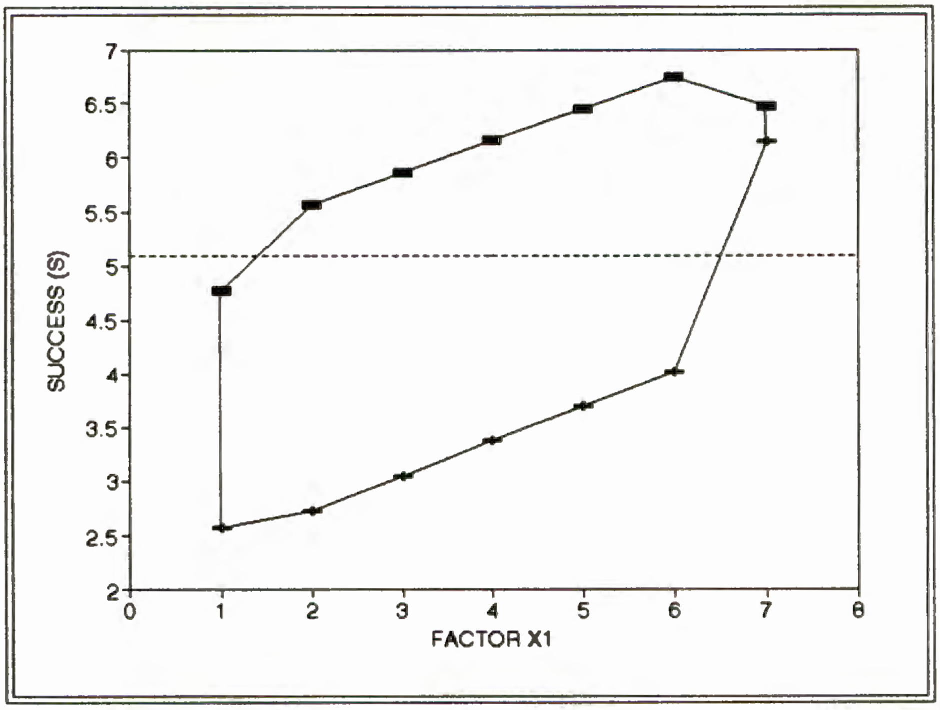
VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
* X_1	4,60	1,40
X_3	4,40	2,80
* X_4	5,00	1,60
X_5	4,60	3,00
X_6	5,00	4,40

* Highest difference between optimum values

Figure 6.7

Maximum and Minimum S Values for Variable X_1 (Top Management Involvement)

MAXIMUM X1	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X2	6.00	6.00	6.00	6.00	6.00	6.00	6.00
X3	6.00	6.00	6.25	6.50	6.75	7.00	7.00
X4	2.00	7.00	7.00	7.00	7.00	7.00	5.00
X5	5.00	5.00	5.50	6.00	6.50	7.00	6.00
X6	6.00	6.00	6.25	6.50	6.75	7.00	7.00
S(MAX)	4.77	5.57	5.86	6.16	6.45	6.74	6.47

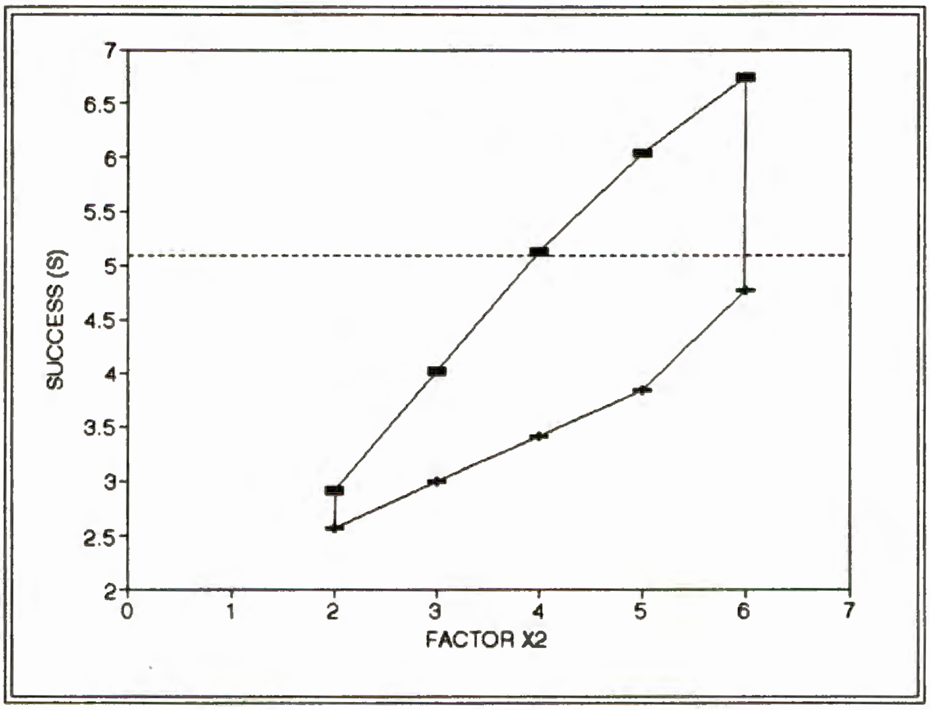


MINIMUM X1	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X2	2.00	2.00	2.25	2.50	2.75	3.00	6.00
X3	2.00	2.00	2.25	2.50	2.75	3.00	7.00
X4	2.00	2.00	2.25	2.50	2.75	3.00	5.00
X5	2.00	3.00	2.75	2.50	2.25	2.00	5.00
X6	2.00	1.00	1.75	2.50	3.25	4.00	6.00
S(MIN)	2.58	2.72	3.05	3.37	3.70	4.02	6.15

Figure 6.8

Maximum and Minimum *S* Values for Variable X_2 (EDP Centre/Function)

MAXIMUM X2	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1		2.00	6.00	3.00	6.00	6.00	
X3		2.00	3.00	5.00	5.00	7.00	
X4		1.00	3.00	7.00	7.00	7.00	
X5		3.00	2.00	5.00	6.00	7.00	
X6		3.00	4.00	5.00	6.00	7.00	
S(MAX)		2.91	4.02	5.13	6.04	6.74	



MINIMUM X2	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1		1.00	1.33	1.67	2.00	1.00	
X3		2.00	2.00	2.00	2.00	6.00	
X4		2.00	1.67	1.33	1.00	2.00	
X5		2.00	2.33	2.67	3.00	5.00	
X6		2.00	3.33	4.67	6.00	6.00	
S(MIN)		2.58	3.00	3.42	3.84	4.77	

X_3 - System output characteristics

The maximum and minimum success levels increased as the system output characteristics improved (Figure 6.9). This indicates that X_3 does play an important role as a factor influencing risk. X_6 (Quality of service from EDP staff/centre) and X_1 (Top management involvement) also appears to have a significant influence in this case.

Table 6.9

VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
* X_1	4,67	1,92
X_2	5,25	3,33
X_4	5,00	4,17
X_5	5,25	3,50
* X_6	6,25	2,75

* Highest difference between optimum values

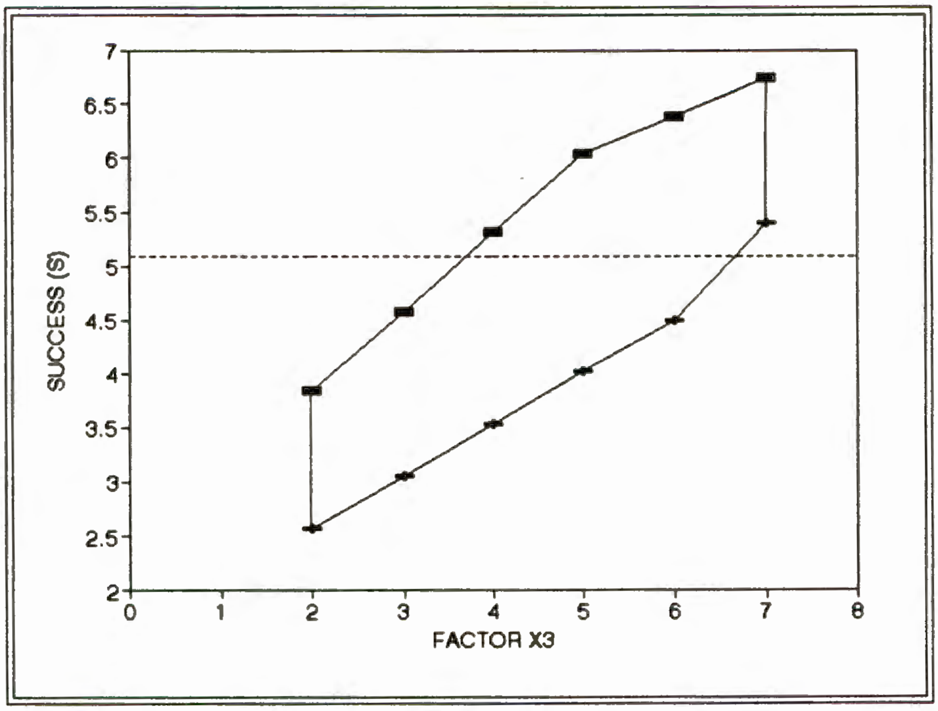
X_4 - Effect of system on users

As in the previous case, this graphic representation (Figure 6.10) indicates that X_4 will definitely impact on the different success levels. The broad 'band' also indicates that the remaining factors will play a significant role in changing the success levels. This is also evident from Table 6.10 where it can be seen that the differences between mean optimum values are generally high. X_1 and X_6 have the highest difference and could therefore be regarded as the most important ones to be adjusted when the success level needs to be changed.

Figure 6.9

Maximum and Minimum *S* Values for Variable X_3 (System Output Characteristics)

MAXIMUM X3	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1		2.00	3.33	4.67	6.00	6.00	6.00
X2		5.00	5.00	5.00	5.00	5.50	6.00
X4		1.00	3.00	5.00	7.00	7.00	7.00
X5		3.00	4.00	5.00	6.00	6.50	7.00
X6		6.00	6.00	6.00	6.00	6.50	7.00
S(MAX)		3.84	4.58	5.31	6.04	6.39	6.74

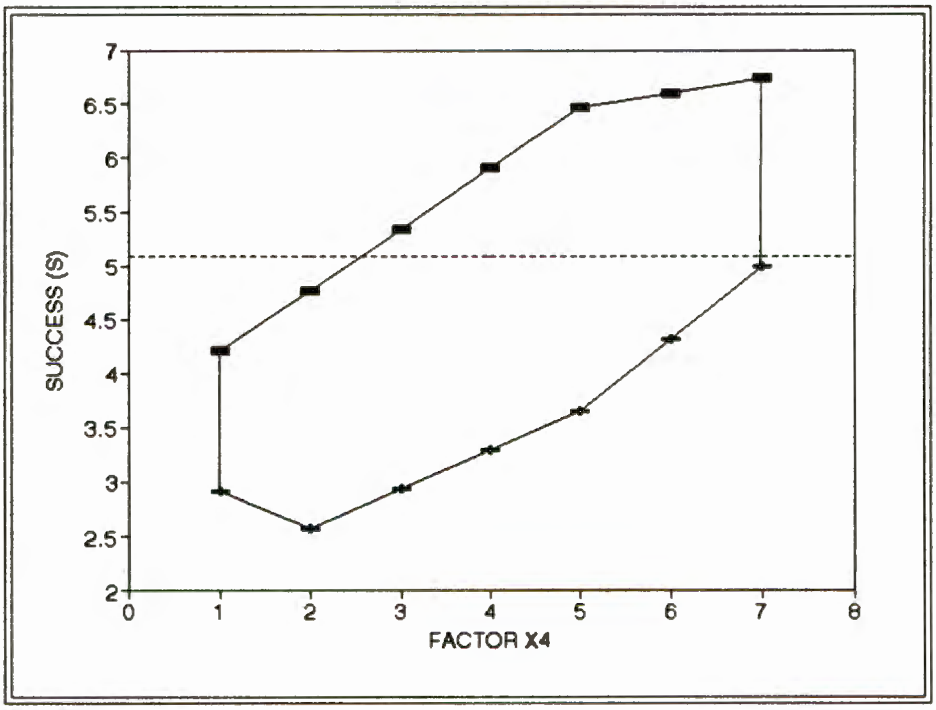


MINIMUM X3	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1		1.00	1.25	1.50	1.75	2.00	4.00
X2		2.00	2.50	3.00	3.50	4.00	5.00
X4		2.00	3.00	4.00	5.00	6.00	5.00
X5		2.00	2.50	3.00	3.50	4.00	6.00
X6		2.00	2.25	2.50	2.75	3.00	4.00
S(MIN)		2.58	3.05	3.53	4.01	4.49	5.40

Figure 6.10

Maximum and Minimum *S* Values for Variable X_4 (Effect of System on users)

MAXIMUM X4	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1	4.00	4.75	5.50	6.25	7.00	6.50	6.00
X2	5.00	5.25	5.50	5.75	6.00	6.00	6.00
X3	4.00	4.75	5.50	6.25	7.00	7.00	7.00
X5	3.00	3.75	4.50	5.25	6.00	6.50	7.00
X6	5.00	5.50	6.00	6.50	7.00	7.00	7.00
S(MAX)	4.21	4.78	5.34	5.91	6.47	6.61	6.74



MINIMUM X4	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1	2.00	1.00	1.33	1.67	2.00	3.50	5.00
X2	2.00	2.00	2.67	3.33	4.00	4.00	4.00
X3	2.00	2.00	2.67	3.33	4.00	4.00	4.00
X5	3.00	2.00	2.00	2.00	2.00	3.50	5.00
X6	3.00	2.00	2.00	2.00	2.00	2.50	3.00
S(MIN)	2.91	2.58	2.93	3.29	3.65	4.32	4.99

Table 6.10

VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
* X_1	5,71	2,36
X_2	5,64	3,14
X_3	5,93	3,14
X_5	5,14	2,79
* X_6	6,29	2,36

* Highest difference between optimum values

<u>X_5 - Issues concerning conventional system characteristics</u>

The ascending curves for both maximum and minimum levels of success once again indicate that factor X_5 will influence the success of a system. It can also be seen from Figure 6.11 that the influence of the remaining factors decreases when the success levels (and X_5) are increased. X_1, X_4 and X_6 have the highest differences between their optimum values and could be regarded as the other major role players in this case.

Table 6.11

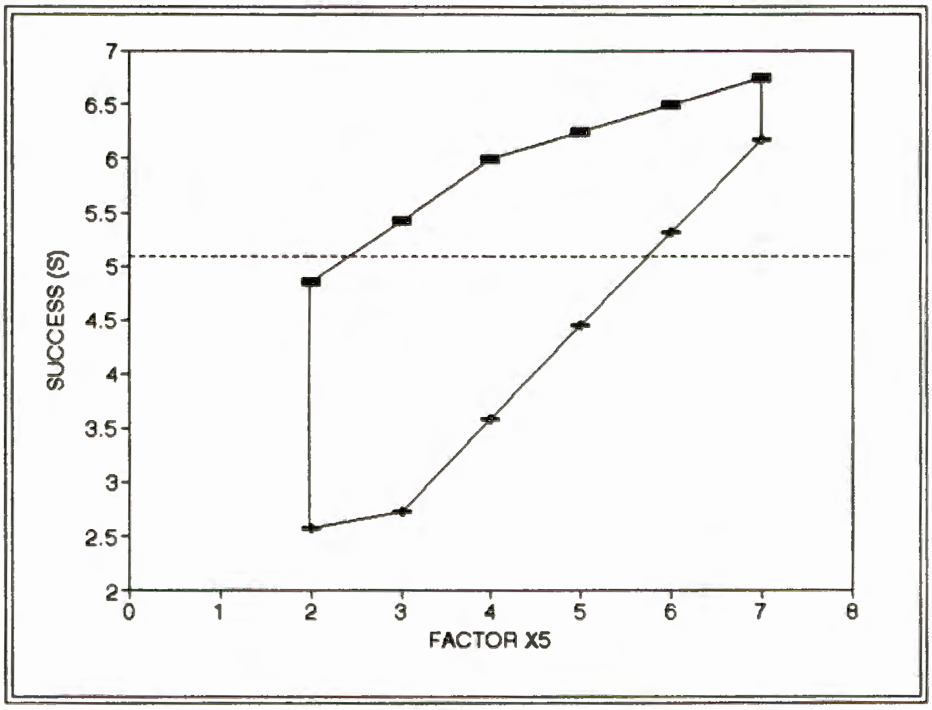
VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
* X_1	6,00	3,08
X_2	5,50	3,67
X_3	6,08	4,08
* X_4	6,25	3,25
* X_6	6,33	3,25

* Highest difference between optimum values

Figure 6.11

Maximum and Minimum *S* Values for Variable X_5
(Issues concerning conventional system characteristics)

MAXIMUM X5	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1		6.00	6.00	6.00	6.00	6.00	6.00
X2		4.00	5.00	6.00	6.00	6.00	6.00
X3		5.00	5.50	6.00	6.33	6.67	7.00
X4		4.00	5.50	7.00	7.00	7.00	7.00
X6		6.00	6.00	6.00	6.33	6.67	7.00
S(MAX)		4.86	5.42	5.99	6.24	6.49	6.74



MINIMUM X5	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1		1.00	2.00	2.75	3.50	4.25	5.00
X2		2.00	2.00	3.00	4.00	5.00	6.00
X3		2.00	2.00	3.25	4.50	5.75	7.00
X4		2.00	2.00	2.75	3.50	4.25	5.00
X6		2.00	1.00	2.25	3.50	4.75	6.00
S(MIN)		2.58	2.72	3.59	4.45	5.32	6.18

X_6 - Quality of service from EDP Staff/Centre

Figure 6.12 is the graphic representation of the different success levels when variable X_6 is restricted to 1, 2, ..., 7.

The slope of both curves (maximum and minimum) indicates that the higher the quality of service received, the more successful systems would be. The high differences between the remaining variable's optimum values show that they all have a significant role to play. Variables X_1, X_3 and X_4 have the biggest differences in their optimum values.

Table 6.12

VARIABLE	MEAN OPTIMUM VALUE AT MAXIMUM	MEAN OPTIMUM VALUE AT MINIMUM
* X_1	5,43	1,71
X_2	5,57	3,43
* X_3	5,61	2,43
* X_4	5,89	1,86
X_5	4,57	2,71

* Highest difference between optimum values

6.2.2.2 Conclusion

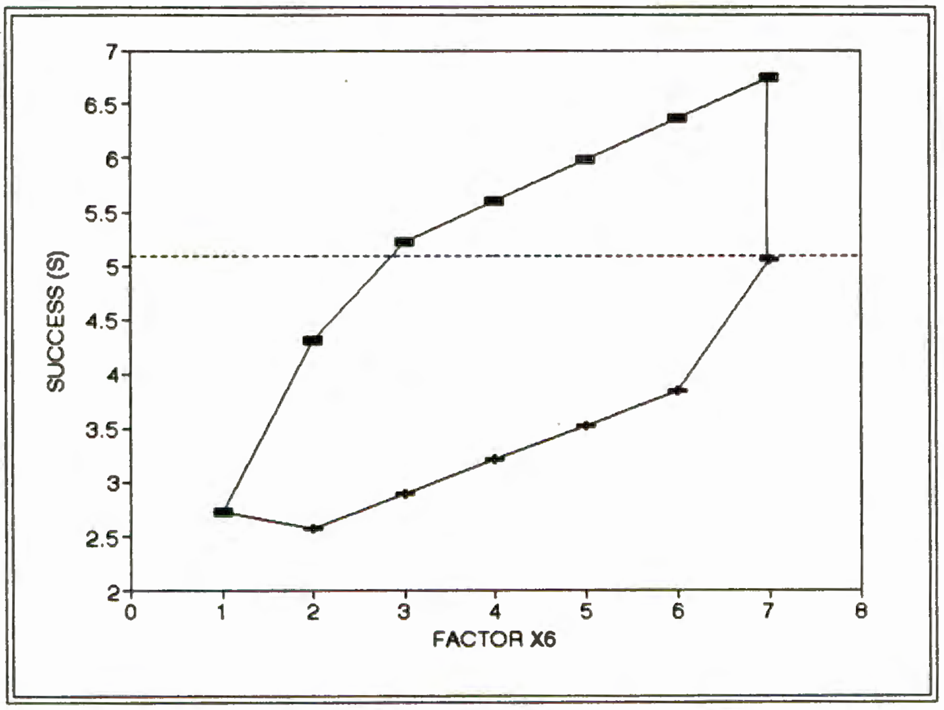
The graphic representations (Figures 6.7 to 6.12) and the accompanying optimum values for each variable showed that the success of a system could be changed by changing the different factors.

As in the case of the risk model, a "satisfactory" regression model was constructed consisting of various "independent" variables. Application of the optimising technique then indicated which variables are the most important ones to be adjusted. The optimum values also indicated how they should be adjusted to improve the success of a computer system optimally.

Figure 6.12

Maximum and Minimum *S* Values for Variable X_6 (Quality of Service from EDP Staff/Centre)

MAXIMUM X6	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1	4.00	4.00	6.00	6.00	6.00	6.00	6.00
X2	4.00	5.00	6.00	6.00	6.00	6.00	6.00
X3	4.00	3.00	6.00	6.00	6.50	6.75	7.00
X4	4.00	5.00	6.00	6.00	6.50	6.75	7.00
X5	3.00	4.00	3.00	4.00	5.00	6.00	7.00
S(MAX)	2.72	4.30	5.23	5.61	5.99	6.37	6.74



MINIMUM X6	1.00	2.00	3.00	4.00	5.00	6.00	7.00
X1	2.00	1.00	1.25	1.00	1.75	2.00	3.00
X2	2.00	2.00	2.75	3.00	4.25	5.00	5.00
X3	2.00	2.00	2.00	2.00	2.00	2.00	5.00
X4	2.00	2.00	1.75	1.00	1.25	1.00	4.00
X5	3.00	2.00	2.25	2.00	2.75	3.00	4.00
S(MIN)	2.72	2.58	2.89	3.21	3.53	3.84	5.05

Although it appeared, for purposes of the Success model, that all 6 variables are important, the following three constantly figured as major role players:

X_1 - Top management involvement
X_4 - Effect of system on users
X_6 - Quality of service from EDP Staff/Centre

6.3 SUMMARY

Chapter 6 detailed the optimisation techniques applied to the linear regression models, for Risk and Success, obtained in Chapter 5. The models were optimised for each independent variable restricted to a fixed value (1, ..., 7). Graphic representations were produced where the influence of each independent variable on Risk/Success could be clearly observed. Through this technique three factors each for Risk and Success, were identified as appearing to be major role players in determining Risk and Success levels.

CHAPTER 7

ALLOCATION OF RESOURCES

7.1 INTRODUCTION

The basic aim of this study remains to formulate a suitable model with which resources could be allocated to different computer based systems. Such a model should include issues such as importance and risk and success of systems.

Chapter 7 will discuss the formulating of a model which deals with conflicting interests (factors), the allocation of financial resources to systems based on developed models during the research and finally, a direct allocation of resources to specific systems taking into account the calculated importance, risk and success of that specific system.

7.2 A MODEL TO RECONCILE CONFLICTING FACTORS

The previous chapters were mainly used to establish certain factors which will influence the risk or success of a system. Models, in the form of linear regression equations, were developed and coefficients, in the equation were estimated using standard linear regression techniques. Based on their contribution to R^2, certain factors were then eliminated. This whole process (Chapter 5), led to the following two regression equations:

$$\text{RISK} = 3{,}3961 + 0{,}3440\text{OldRisk} - 0{,}1018F_1 - 0{,}1345F_2 + 0{,}1974F_4 - 0{,}1869F_5 - 0{,}1316F_6 \qquad (R^2 = 0{,}94)$$

$$\text{SUCCESS} = 0{,}9926 + 0{,}1464X_1 + 0{,}1536X_4 + 0{,}1163X_5 + 0{,}1305X_6 + 0{,}1595X_7 + 0{,}1583X_8 \qquad (R^2 = 0{,}92)$$

where

OldRisk	=	Profile risk based on state variables
F_1	=	Physical security
F_2	=	Technology used
F_4	=	Recent changes to system or key personnel
F_5	=	How managers (EDP and Users) act, e.g. attitude, support, etc.
F_6	=	Communication between DP Department and users
X_1	=	Top management involvement
X_4	=	EDP Centre/Function
X_5	=	System output characteristics
X_6	=	Effect of system on users
X_7	=	Issues concerning conventional system characteristics
X_8	=	Quality of service from EDP Staff/Centre

Factors eliminated were the following:

F_3	=	Training EDP personnel have undergone or are at present receiving
F_7	=	Logical security and quality of controls
X_2	=	EDP Staff/User relationship
X_3	=	EDP Staff quality

It is obvious from the above list of factors that they are interdependent as well as conflicting. This means that if, for example, resources are allocated to one of them it might improve (or weaken) an other factor(s). Should resources be spent on F_6 (Communication between DP and Users) chances are, for example, that the effect of the system on the users (X_6) would improve. Improvement in the quality of service from the EDP Staff/Centre (X_8) is also possible when adjusting F_6. Furthermore, factors F_5 and X_1 both refer to management involvement and are therefore seen as being exactly the same.

A model to make provision for these apparent contradictions was formulated and was based on a model discussed in [47].

The objective of this model was to suggest a technique whereby the success of database environments could be evaluated. Briefly, it consists of the following steps:

- The formulation of 3 hypothetical models (for users, database personnel and managers) in the form of linear regression equations.

- Through the application of standard linear regression techniques on data obtained from questionnaires, the coefficients in the three equations were estimated.

- A single linear regression equation between success and all independent variables, chosen from the 3 equations, was then formulated.

- A linear program to optimise the success was formulated next. This linear program contains, among others, two constraints to keep success levels for users and database personnel above predefined levels. These two constraints were in the form of regression equations as mentioned above.

Following the same principles, the REG procedure from the SAS System was used to find a linear regression equation between success of a system and all the mentioned risk **and** success factors.

The procedure was then repeated also to find a linear regression equation between the risk of a system and all the same risk **and** success factors. As factors F_5 (How managers, EDP and users, act) and X_1 (Top management involvement) are regarded as the same factor, which was rated only once for both risk and success models, it only appears once in the above-mentioned linear regression equations.

The two equations found were:

$$\begin{aligned}\text{Success} &= 1{,}0052 - 0{,}0409\text{OldRisk} - 0{,}0586F_1 - 0{,}0016F_2 + 0{,}0448F_3 + \\ &\quad 0{,}0713F_4 + 0{,}1854F_5 - 0{,}1164F_6 + 0{,}0674F_7 - 0{,}0452\,X_2 + \\ &\quad 0{,}0337X_3 + 0{,}0732X_4 + 0{,}2042X_5 + 0{,}1668X_6 + 0{,}1522X_7 \\ &\quad + 0{,}1638X_8 \\ \text{with } R^2 &= 0{,}95\end{aligned}$$

and the F-test: 26,83 with probability > F 0,0001

$$\begin{aligned}\text{Risk} &= 3{,}2252 + 0{,}3354\text{OldRisk} - 0{,}0627F_1 - 0{,}0945F_2 + 0{,}0599F_3 \\ &\quad + 0{,}2092F_4 - 0{,}1801F_5 - 0{,}1387F_6 - 0{,}0289F_7 + 0{,}0191\,X_2 - \\ &\quad 0{,}0537X_3 + 0{,}0313X_4 + 0{,}0413X_5 - 0{,}0075X_6 - 0{,}0473X_7 - \\ &\quad 0{,}0509X_8 \\ \text{with } R^2 &= 0{,}96\end{aligned}$$

and the F-test: 33,36 with probability > F 0,0001

With the help of linear programming the success of the computer-based systems can now be maximised. The assumption was that the risk of a system may not be higher than a predetermined level.

To do this, a linear program was formulated as follows:

Maximise success $= a_0 + a_1Y_1 + a_2Y_2 + \ldots + a_kY_k$

Subject to:

$$\begin{aligned}
\lambda_1Y_{11} + \lambda_2Y_{21} + \ldots 3+ \lambda_nY_{n1} - Y_1 &= 0 \\
\lambda_1Y_{12} + \lambda_2Y_{22} + \ldots + \lambda_nY_{n2} - Y_2 &= 0 \\
&. \\
&. \\
&. \\
\lambda_1Y_{1k} + \lambda_2Y_{2k} + \ldots + \lambda_nY_{nk} - Y_k &= 0 \\
b_0 + b_1Y_1 + b_2Y_2 + \ldots + b_kY_k &\leq r \qquad (7.1) \\
Y_p &= q \qquad (7.2) \\
\lambda_1 + \lambda_2 + \ldots + \lambda_n &= 1 \\
\lambda 1, \lambda 2, \ldots, \lambda n &\geq 0
\end{aligned}$$

- $Y_1, Y_2, \ldots, Y_k$ unlimited sign

- r is the pre-determined minimum risk level that would be acceptable

- $k = 15$, $n = 36$, $1 \leq p \leq 15$, $1 \leq q \leq 7$

- Y_i = Factors in linear regression equation, $1 \leq i \leq 15$

- a_0 = 1,0052 a_1 = -0,0409 a_2 = -0,0586
  a_3 = -0,0016 a_4 = 0,0448 a_5 = 0,0713
  a_6 = 0,1854 a_7 = -0,1164 a_8 = 0,0674
  a_9 = -0,0452 a_{10} = 0,0337 a_{11} = 0,0732
  a_{12} = 0,2042 a_{13} = 0,1668 a_{14} = 0,1522
  a_{15} = 0,1638

- $b_0 = 3{,}2252$ $b_1 = 0{,}3354$ $b_2 = -0{,}0627$
  $b_3 = -0{,}0945$ $b_4 = 0{,}0599$ $b_5 = 0{,}2092$
  $b_6 = -0{,}1801$ $b_7 = -0{,}1387$ $b_8 = -0{,}0289$
  $b_9 = 0{,}0191$ $b_{10} = -0{,}0537$ $b_{11} = 0{,}0313$
  $b_{12} = 0{,}0413$ $b_{13} = -0{,}0075$ $b_{14} = -0{,}0473$
  $b_{15} = -0{,}0509$

This linear program is almost exactly the same as the ones formulated in Chapter 6. The main differences are the fact that the factors influencing different issues (risk and success) are incorporated in one objective function and the additional constraint (7.1) to provide for pre-determined risk levels. The decision variables may again be limited to certain levels to determine the impact of remaining variables on the success of a system (7.2).

The procedure LP from the SAS System was used once again to solve the linear program.

The linear program was solved for r = 1, 2 ..., 7 in the risk limitation (7.1). The different solutions, as measured on a 7-point scale, were as follows:

Table 7.1

r	MAXIMUM SUCCESS
1	Non-feasible solution
2	5,79245
3	5,79245
4	5,79245
5	5,79245
6	5,79245
7	5,79245

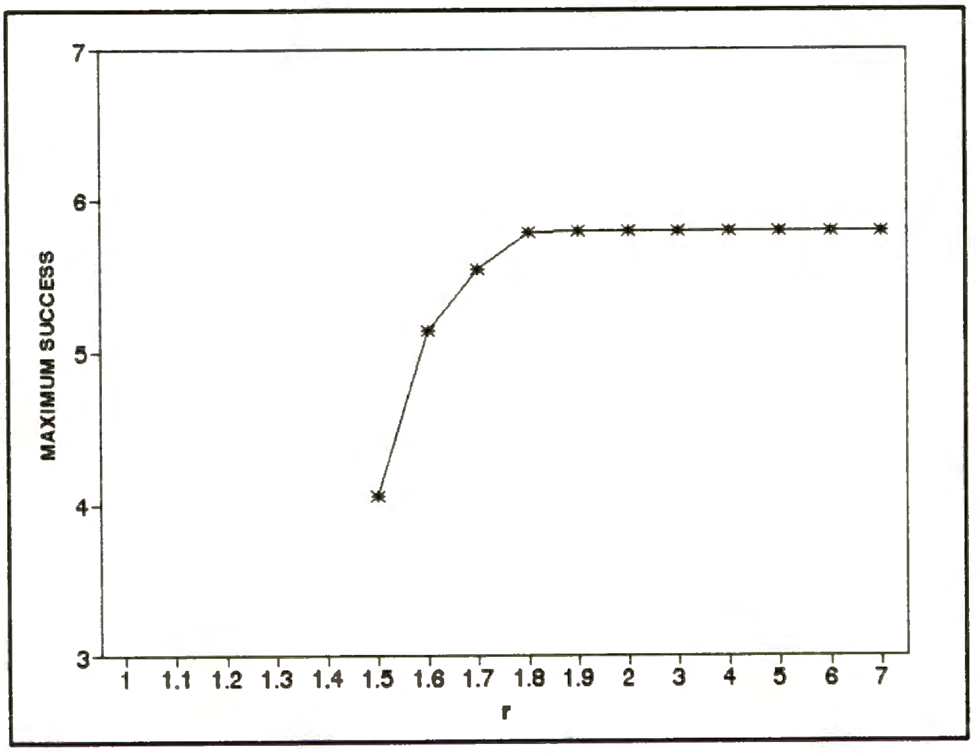
Non-feasible solutions are possible and is a result of the area of experience which did not include enough combinations of different data points. As can be seen from Table 7.1, all other solutions for the different r-values are the same. This is also because of the available data points. One of the case studies had a risk-level of 2 and a success-level of 7 which eliminates the addition of the extra limitation (7.1) in this particular model.

To illustrate the effect of the model, without being limited by the inappropriateness of some of the available data points, on how to compensate for conflicting factors, the linear program was again solved for r=1,1 to 1,9 in steps of 0,1. The different solutions are incorporated into Table 7.1 and are presented in Table 7.2:

Table 7.2

r	MAXIMUM SUCCESS
1,0	Non-feasible solution
1,1	Non-feasible solution
1,2	Non-feasible solution
1,3	Non-feasible solution
1,4	Non-feasible solution
1,5	4,05
1,6	5,14
1,7	5,54
1,8	5,78
1,9	5,79
2,0	5,79
3,0	5,79
4,0	5,79
5,0	5,79
6,0	5,79
7,0	5,79

Graphically, the maximum success, can be presented as follows:



It can be seen from Table 7.2 and the graph that a certain price has to be paid if pre-determined risk levels are desirable. The maximum success when r $\leq$ 1,9 is 5,79 as opposed to the maximum of 4,05 when r $\leq$ 1,5. The price paid here is a decrease of 1,74 on the 7-point scale which is a significant change when taking the huge amounts some firms spend on the IT needs into account.

Normalising the success figures of Table 7.2, and expressing them as percentages, shows that there is a 7% difference between a risk level of 1,5 and one of 1,9.

The model developed in this paragraph has the advantage of taking both risk and success factors into consideration in an effort to alleviate conflicting interests. It has a built-in mechanism to ensure that no discrimination against risk has taken place because the risk is forced to be below an accepted pre-determined level. The determination of cost (and ultimate allocation of resources) can now be incorporated into this model and forms the contents of the paragraphs to follow.

7.3 MODELS TAKING COST INTO CONSIDERATION

Whenever management decides on improving on the quality of their computerised systems (which may be interpreted as lowering risk levels and lifting of success levels), they have to take costs involved into consideration. Improving a computer-based system implies that the variables or factors influencing that system's risk or success should be changed. The best combination for the various levels of factors involved should be found while considering the cost to change each factor to the desired level.

In general we may assume that the costs to adjust the variables X_1, ... X_7 with one unit are respectively C_1, ..., C_7. Furthermore, assume that a total of M monetary resources is available to spend on the different variables in order to change the success levels. These extra constraints can easily be incorporated in the model, formulated in paragraph 7.2, by adding the following to the linear program problem:

$$C_1X_1 + C_2X_2 + \ldots + C_7X_7 \leq M$$

The addition of this extra constraint posed three major problems.

Firstly, it is assumed that the cost for each variable increased linearly. This issue was not investigated during this research project and should be treated as an important consequence of the study which needs further research.

Secondly, when applying the model to various specific systems it may be difficult to establish a value for M. Paragraph 7.4 suggests a direct resource allocation model for allocating resources to different systems. The model takes importance, risk and success for each system into account and the data used are the actual data used throughout this project.

The third problem relates to the determining of $C_1, \ldots, C_7$. A method to try and solve this problem will now be discussed, but before the discussion, the reader should take note of the fact that it is a proposed solution and was not tested during the research. There were a number of reasons for not testing the method in the organisation under review. As mentioned in earlier chapters, geographical problems made it very difficult to consult with all the personnel involved. This would mean that only estimated figures would be provided which could obviously give wrong or misplaced results. Informal discussions held with senior data-processing personnel also revealed that costing statistics were not kept in such a detailed form as to facilitate an estimation of financial resources spent on specific factors.

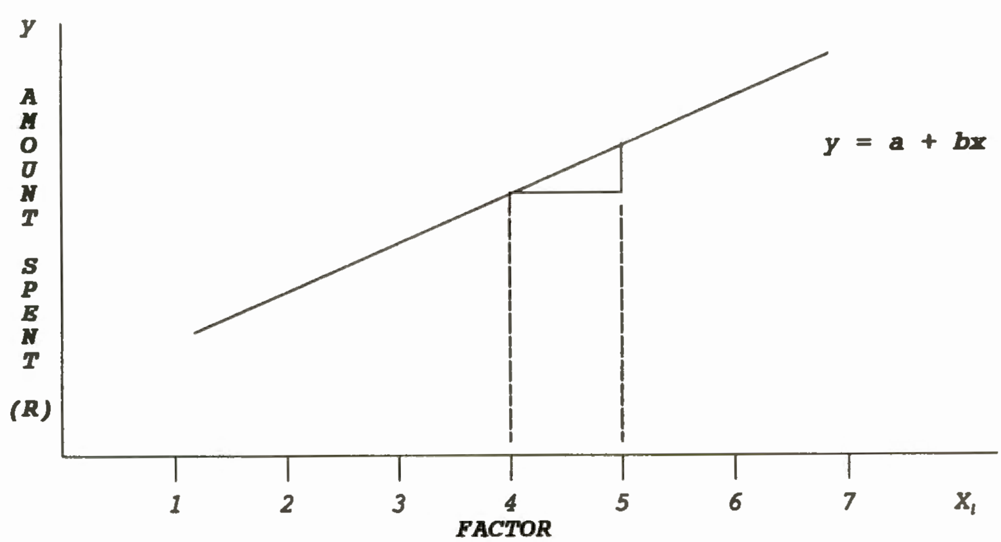
There were thirty-six different systems used in the research project. Various factors pertaining to all thirty-six systems were determined. They were then separately rated and evaluated for each of the systems.

Consider one of these factors, say X_i. It may be possible to obtain for each of the thirty-six systems the amount spent, for a certain time period, on this specific factor X_i. In other words, through interviewing the system's project leader/manager or by investigating costs for this system and then identify the portion spent on factor X_i, it may be possible to establish a reasonably accurate amount spent. Doing this for all thirty-six systems, a set of thirty-six points would be available, the coordinates being (rating on 7-point scale for factor X_i; amount spent on X_i).

The thirty-six points can now be plotted on a graph and through ordinary simple linear regression, on a two-variable model, a relationship of $y=a + bx$ can be formulated and a and b can be estimated [96]. This technique assumes that costs increase linearly. Other techniques, to estimate relationships and coefficients, [84], should be used should costs not increase linearly. Figure 7.3.1. is a hypothetical example of the method explained.

The value of b in the equation represents the slope of the curve. This means that b practically measures the average change in y for a one-unit change in x, see [96]. In our example it would mean that b indicates the average change in money spent (the cost) when changing the factor's rating one unit on the 7-point scale. It is therefore suggested that the value b obtained be used to estimate the cost factor C_i for that variable.

Figure 7.3.1



Available cost figures to change each specific factor will enable us to expand the constraints and the model to make provision for a specific system (i.e. factors for a specific system).

Let us consider the following:

The linear equation, which can be used to optimise success, is available and was formulated in Paragraph 7.2.

For any one specific system the following would be available:

FACTOR	GIVEN 7-POINT EVALUATION FOR EACH FACTOR	DESIRED LEVEL ON 7-POINT SCALE	COST TO ADJUST FACTOR WITH ONE UNIT	TOTAL COST
1	e_1	e_1^*	C_1	$\mid e_1^*-e_1 \mid C_1$
2	e_2	e_2^*	C_2	$\mid e_2^*-e_2 \mid C_2$
3	e_3	e_3^*	C_3	$\mid e_3^*-e_3 \mid C_3$
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
n	e_n	e_n^*	C_n	$\mid e_n^*-e_n \mid C_n$

It is now possible to once again maximise the success function as given in Paragraph 7.2. The following constraint was added to incorporate the cost for adjusting the factors from their actual values to their desired levels:

$$\mid e_1^* - e_1 \mid C_1 + \mid e_2^* - e_2 \mid C_2 + \ldots + \mid e_n^* - e_n \mid C_n \leq T_{Ri}$$

Where T_{Ri} is the total monetary resources available for system i.

This new constraint, when dealing with specific systems, brings us back to the second major problem mentioned earlier: The determination of an acceptable T_{Ri} - value.

The next paragraph deals with this problem.

7.4 DIRECT ALLOCATION OF RESOURCES TO SPECIFIC SYSTEMS

This paragraph suggests that a direct resource allocation strategy can be formulated taking the importance, risk and success of different computer-based systems into account.

Chapter 5 concluded with a table which provided for each system a numeric measure of risk, success and importance. The model to be followed took these three issues into account when allocating resources to different systems. Answers suggested by the model could therefore be regarded as sufficient for use or it may be used as the T_{Ri} - value (total resources available per system) when applying the cost models in Paragraph 7.3.

The model may be formulated as follows:

$$T_{Ri} = I_i[\alpha\delta_{Si} + \beta\delta_{Ri}]$$

where:

- T_{Ri} is the total resources for system i;
- I_i is the perceived importance of system i;
- α is an importance weight factor associated with the success of computer-based systems; and
- β is an importance weight factor associated with the Risk of computer-based systems.

$$\delta_{Si} = \begin{cases} 0 \text{ when } S_i \geq S^* \\ S^* - S_i \text{ when } S_i < S^* \end{cases}$$

S_i = Current success level for system i

S^* = Desired success level for all systems

$$\delta_{Ri} = \begin{cases} 0 \text{ when } R_i \leq R^* \\ R_i - R^* \text{ when } R_i > R^* \end{cases}$$

R_i = Current risk level for system i

R^* = Desired risk level for all systems

The importance weight factors could be evaluated by using the same importance scale described in Chapter 4 in Table 4.1. Applying this technique of pair-wise comparisons may result in the following matrices which are examples for four options that may be obtained through values selected from the importance scale (Table 4.1):

Option 1: (A value of 3 selected from the importance scale)

Weight factor comparison matrix

	RISK	SUCCESS	EIGENVECTOR	NORMALISED VALUE
RISK	1,0000	3,0000	0,9487	0,75
SUCCESS	0,3333	1,0000	0,3162	0,25

The one weight factor is slightly more important than the other one (in this example, risk is slightly more important than success).

Explanation - Experience and judgement suggest that one weight factor is slightly more important than the other

Option 2: (A value of 5 selected from the importance scale)

Weight factor comparison matrix

	RISK	SUCCESS	EIGENVECTOR	NORMALISED VALUE
RISK	1,0000	5,0000	0,9806	0,83
SUCCESS	0,2000	1,0000	0,1961	0,17

The one weight factor (risk) is strongly more important that the other one (success).

Explanation - Experience and judgement indicate that one weight factor is considerably more important than the other.

Option 3: (A value of 7 selected from the importance scale)

Weight factor comparison matrix

	RISK	SUCCESS	EIGENVECTOR	NORMALISED VALUE
RISK	1,0000	7,0000	0,9899	0,88
SUCCESS	0,1429	1,0000	0,1414	0,12

The one weight factor (risk) is demonstrably more important than the other one (success).

Explanation - One weight factor is strongly more important than the other one, and this importance has been demonstrated.

Option 4: (A value of 9 selected from the importance scale)

Weight factor comparison matrix

	RISK	SUCCESS	EIGENVECTOR	NORMALISED VALUE
RISK	1,0000	9,0000	0,9939	0,90
SUCCESS	0,1111	1,0000	0,1104	0,10

The one weight factor (risk) is absolutely more important than the other one (success).

Explanation - The evidence showing one weight factor to be strongly more important is of the highest order of affirmation.

The model was not tested or applied in the research environment but based on the obtained data during the research and hypothetical values for α, β, S^* and R^* the following example will prove the usefulness and easy use of the model:

Choose $\alpha = 0{,}25$ and $\beta = 0{,}75$. This means that, according to Option 1 above, risk is perceived to be slightly more important than success when allocating resources. Furthermore, let the desired risk level (R^*) for all systems be 2,5 and the desired success level (S^*) be equal to 6 on a 7-point scale. Applying the model will result in percentage allocations to the thirty-six different systems used in the research project as set out in Table 7.3. According to this table, system 18, for example, will receive 10,04% of the total budget available for allocating to all 36 computerised systems. This suggested percentage allocation could be regarded as a proposed direct allocation to system 18 which has taken into account the risk, success and perceived importance of all computerised systems included in the model. It may also be used as the total resources available for system 18 when applying the cost model as suggested in paragraph 7.3.

Table 7.3

SYSTEM	IMPORT-ANCE (I_i)	RISK (R_i)	$\beta\delta_{Ri}$	SUCCESS (S_i)	$\alpha\delta_{Si}$	$I_i[\alpha\delta_{Si}+\beta\delta_{Ri}]$	$T_{Ri}/\Sigma T_{Ri}$ x 100
1	0,0037	3,5	0,750	5	0,25	0,0037	00,50
2	0,0264	3,5	0,750	6	0,00	0,0198	02,70
3	0,0089	2,5	0,000	6	0,00	0,0000	00,00
4	0,0051	2,0	0,000	6	0,00	0,0000	00,00
5	0,0049	2,5	0,000	5	0,25	0,0012	00,16
6	0,0115	1,5	0,000	6	0,00	0,0000	00,00
7	0,0046	2,0	0,000	4	0,50	0,0023	00,31
8	0,0189	2,0	0,000	6	0,00	0,0000	00,00
9	0,0086	3,0	0,375	6	0,00	0,0032	00,44
10	0,0136	2,0	0,000	4	0,50	0,0068	00,93
11	0,0178	2,0	0,000	6	0,00	0,0000	00,00
12	0,0188	3,0	0,375	5	0,25	0,0118	01,61
13	0,0141	2,5	0,000	6	0,00	0,0000	00,00
14	0,0464	3,0	0,375	6	0,00	0,0174	02,37
15	0,0127	3,0	0,375	3	0,75	0,0143	01,95
16	0,0589	3,0	0,375	5	0,25	0,0368	05,01
17	0,0048	3,0	0,375	4	0,50	0,0042	00,57
18	0,0536	4,0	1,125	5	0,25	0,0737	10,04
19	0,1181	3,5	0,750	6	0,00	0,0886	12,07
20	0,1031	3,5	0,750	6	0,00	0,0773	10,53
21	0,0165	1,5	0,000	4	0,50	0,0083	01,13
22	0,0762	3,5	0,750	5	0,25	0,0762	10,38
23	0,0356	2,5	0,000	5	0,25	0,0089	01,21
24	0,0558	2,0	0,000	7	0,00	0,0000	00,00
25	0,0163	3,0	0,375	6	0,00	0,0061	00,83
26	0,0418	2,5	0,000	7	0,00	0,0000	00,00
27	0,0173	2,0	0,000	5	0,25	0,0043	00,59
28	0,0104	3,0	0,375	4	0,50	0,0091	01,24
29	0,0309	2,5	0,000	5	0,25	0,0077	01,05
30	0,0241	3,5	0,750	5	0,25	0,0241	03,28
31	0,0457	5,5	2,250	3	0,75	0,1371	18,67
32	0,0449	4,0	1,125	5	0,25	0,0617	08,40
33	0,0048	3,5	0,750	2	1,00	0,0084	01,14
34	0,0157	3,5	0,750	5	0,25	0,0157	02,14
35	0,0050	3,0	0,375	4	0,50	0,0044	00,60
36	0,0045	2,0	0,000	5	0,25	0,0011	00,15

7.5 SUMMARY

As the interdependence between factors influencing a computerised system's risk and success, as well as their conflicting nature, plays such an important role, a model to deal with these contradictory issues was suggested in Chapter 7.

The chapter concluded by suggesting a model to allocate resources to different computerised systems. This model takes into account the risk, success and importance of a system and accordingly allocated resources to it.

CHAPTER 8

SUMMARY, CONCLUSION AND RECOMMENDATIONS

8.1 INTRODUCTION

The contents of this chapter will consist of a general summary of what was done during the research project, conclusions on results obtained and recommendations which can be made as a result of the study. Finally, brief comments on possible research emanating from this study will be made.

8.2 SUMMARY

The lack of a resource allocation strategy for management as well as the need for a tool that can be used by Internal Auditors to appraise the allocation of resources to different computerised systems led to this study being undertaken. Different models, pertaining to different issues influencing resource allocations, were developed in order to optimise the utilisation of resources.

8.2.1 Models

Three issues, risk, success and importance of a system, were assumed to be the major issues that would influence management's decisions when deciding on resources for different computer systems.

Importance

Pair-wise comparisons of the different systems were done. These comparisons depend on the judgement of respondents and were used to construct matrices of which the entries then represent an individual's estimate of the relative dominance of one system over another. A measurement scale of perceived importance can then be produced from a set of paired comparisons by using the normalised principal eigenvector of the paired-comparison matrix.

The validity of this scaling approach has been demonstrated in several cases where the scaling results from paired-comparison judgements were very close to the actual empirical relationship. This scale was also used to develop a framework for allocating audit resources as discussed in Chapter 3.

The technique was tested in the research environment by making use of an external consultant with no actual knowledge of the specific systems. Judgements were given based on brief system descriptions. The results proved to be acceptable and the 36 systems used in the research project were then judged by senior EDP Personnel and users. A list, prioritised according to perceived importance, was the final result which was used during the development of an allocation strategy.

Risk

A model where the risk of a computerised system was treated as a dependent variable was developed. Factors influencing this risk were identified and used in the model as independent variables. Data used in this model were obtained through the use of questionnaires where respondents had to evaluate the risk and their factors on a 7-point scale. A total of 36 systems were used in the model.

The data were tested using correlation and linear regression and the following emerged:

- Correlation analysis indicated that linear relationships do exist between risk and each one of the identified factors.

- By applying stepwise linear regression, the "best" set of independent variables was found where R^2 was as high as possible with the number of variables as low as possible.

The linear regression equation found and the variables were as follows:

$$\text{Risk} = 3{,}3961 + 0{,}3440X_1 - 0{,}1018X_2 - 0{,}1345X_3 + 0{,}1976X_4 - 0{,}1869X_5 - 0{,}1316X_6$$

with $R^2 = 0{,}94$. This means that 94% of the variation in Risk is explained by the six (X_1, ..., X_6) independent variables
and the F-Test: 72,28 with probability > F 0,0001

The independent variables were:

X_1 - Profile risk based on state variables
X_2 - Physical security
X_3 - Technology used
X_4 - Recent changes to system or key personnel
X_5 - How managers (EDP and users) act, e.g. support, attitude, etc.
X_6 - Communication between DP Department and users

Success

As in the case with risk, a model with success of computerised systems as dependent variable was developed. The factors influencing success and acting as independent variables in the model were selected from previous research projects found in the literature. 39 factors were chosen. To keep the model as simple as possible the 39 factors were grouped into 8 main factors which were then used for development of a suitable success model.

The data were obtained in the same way as for the risk model and testing of the data indicated that:

- Linear relationships exist between the success of a system and the chosen success factors.

- The selection of a "best" sub-set of independent variables resulted in the following regression equation:

Success = $0{,}9926 + 0{,}1464X_1 + 0{,}1536X_2 + 0{,}1163X_3 + 0{,}1305X_4 + 0{,}1595X_5 + 0{,}1583X_6$

with R^2 = 0,92 which means that 92% of the variation in success is explained by the six (X_1, ..., X_6) independent variables

and the F-test: 58,89 with probability > F 0,0001

The independent variables were:

X_1 - Top management involvement
X_2 - EDP Centre/Function
X_3 - System output characteristics
X_4 - Effect of system on users
X_5 - Issues concerning conventional system characteristics
X_6 - Quality of service from EDP Staff/Centre

8.2.2 Optimisation techniques

The linear regression functions for risk and success were used as objective functions to construct two optimisation problems. These functions were then maximised and minimised for each independent variable restricted to a fixed value (1, ..., 7).

Graphic representations were produced where the influence of each independent variable on risk/success could be clearly observed.

Risk

The following three factors proved to be the major variables to be changed in order to adjust risk levels:

X_4 - Recent changes to system or key personnel

X_5 - How managers (EDP and users) act, e.g. support, attitude, etc.

X_6 - Communication between DP Department and users

Success

Although it appeared from the different graphs that all six variables were important, the following three constantly figured as major role players:

X_1 - Top management involvement

X_4 - Effect of system on users

X_6 - Quality of service from EDP Staff/Centre

8.2.3 Allocation of resources

The identification of risk and success factors clearly indicates that these factors were interdependent and conflicting. This means that should resources be spent on a certain factor it will also have an impact on another factor. To make provision for these apparent contradictions another model, taking risk **and** success into consideration, was developed.

A linear regression equation between the Success of a system and all the risk **and** success factors was found using the SAS System. This procedure was then repeated also to find a linear regression equation between the Risk of a system and all the risk and success factors. The factor, Management Involvement, for both Risk and Success, was rated only once and was therefore included only once in the following models.

The two equations found were:

$$\text{Success} = 1{,}0052 - 0{,}0409F_1 - 0{,}0586F_2 - 0{,}0016F_3 + 0{,}0448F_4 + 0{,}0713F_5 + 0{,}1854F_6 - 0{,}1164F_7 + 0{,}0674F_8 - 0{,}0452X_1 + 0{,}0337X_2 + 0{,}0732X_3 + 0{,}2042X_4 + 0{,}1668X_5 + 0{,}1522X_6 + 0{,}1638X_7$$

with $R^2 = 0{,}95$

and the F-test: 26,83 with probability > F 0,0001

$$\text{Risk} = 3{,}2252 + 0{,}3354F_1 - 0{,}0627F_2 - 0{,}0945F_3 + 0{,}0599F_4 + 0{,}2092F_5 - 0{,}1801F_6 - 0{,}1387F_7 - 0{,}0289F_8 + 0{,}0191X_1 - 0{,}0537X_2 + 0{,}0313X_3 + 0{,}0413X_4 - 0{,}0075X_5 - 0{,}0473X_6 - 0{,}0509X_7$$

with $R^2 = 0{,}96$

and the F-test: 33,36 with probability > F 0,0001

Risk factors:

F_1 - Profile risk based on state variables

F_2 - Physical security

F_3 - Technology used

F_4 - Training EDP personnel have undergone or are at present receiving

F_5 - Recent changes to system or key personnel

F_6 - How managers (EDP and users) act, e.g. attitude, support, etc.

F_7 - Communication between DP Department and users

F_8 - Logical security and quality of controls

Success factors:

X_1 - EDP staff/user relationship

X_2 - EDP staff quality

X_3 - EDP centre/function

X_4 - System output characteristics

X_5 - Effect of system on users

X_6 - Issues concerning conventional system characteristics

X_7 - Quality of service from EDP Staff/Centre

An optimisation problem was formulated to maximise the new dependent variable, success, assuming that risk may not be higher than a predetermined level. To do this, the new risk regression equation was added as an additional constraint, being less than a certain level.

Another constraint was suggested to take cost into account. The constraint was as follows:

$$C_1X_1 + C_2X_2 + \ldots + C_7X_7 \leq M$$

where:

$C_1, \ldots, C_7$ are the cost to adjust variables $X_1, \ldots, X_7$ with one unit respectively.

M is the total of resources available.

A method to estimate the different C-values was suggested. The known C-values enable us to expand the constraints and the model to make provision for a specific system. The new constraint, replacing the above cost constraint, was as follows:

$$| e_1^* - e_1 | C_1 + | e_2^* - e_2 | C_2 + \ldots + | e_n^* - e_n | C_n \leq T_{Ri}$$

where:

e_j^*	is the desired level on a 7 - point scale for factor j;
e_j	is the actual evaluation on a 7 - point scale for factor j;
C_j	is the cost to adjust factor j with one unit; and
T_{Ri}	is the total resources available for system i.

This new constraint posed the problem of finding an acceptable T_{Ri} - value.

A direct resource allocation model was then formulated, taking risk, success and importance of each system into account. Answers suggested by this model could be regarded as sufficient for use, or it may be used as the T_{Ri} - value when applying the suggested cost model.

The model was formulated as follows:

$$T_{Ri} = I_i[\alpha\delta_{Si} + \beta\delta_{Ri}]$$

where:

T_{Ri}	is the total resources for system i;
I_i	is the perceived importance of system i;
α	is an importance weight factor associated with the success of computer-based systems; and
β	is an importance weight factor associated with the Risk of computer-based systems.

$$\delta_{Si} = \begin{cases} 0 \text{ when } S_i \geq S^* \\ S^* - S_i \text{ when } S_i < S^* \end{cases}$$

S_i = Current success level for system i

S^* = Desired success level for all systems

$$\delta_{Ri} = \begin{cases} 0 \text{ when } R_i \leq R^* \\ R_i - R^* \text{ when } R_i > R^* \end{cases}$$

R_i = Current risk level for system i

R^* = Desired risk level for all systems

8.3 CONCLUSION

Prior to making any conclusion it is important once again to note that the research was conducted at one specific organisation. Factors identified, prioritising of systems and data used in developed models are specific to this one organisation. However, the techniques and models developed should be useful in any organisation.

The research project revealed that there are specific factors which will have a definite impact on the risk and success levels of a computerised system (Chapter 5).

These factors which were listed earlier overlap in certain cases. An example is the factor "Management Involvement". Adjusting the level of these overlapping factors will therefore result in a change in both risk and success levels. With these findings the study satisfied the first objective as stated in Chapter 1:

To determine which factors contribute most to:

- *the risk of a computerised system*
- *the success of a computerised system.*

Different techniques to prioritise computer systems were investigated. The one chosen was based on pair-wise comparisons (Chapter 5). This part of the research resulted in a prioritised list of computerised systems based on their perceived importance and thus satisfied the second objective of the study:

To prioritise computerised systems according to their perceived importance.

A risk model and success model were developed and through application of an optimisation technique it was possible to determine which factors are the major role players in determining risk and success. The influence of remaining factors could also be observed (Chapter 6).

The completion of these models also completed the part of the study which was aimed at the third objective:

To determine, through the use of optimisation techniques, which are the major factors which should be changed to maximise the success and minimise the risk of computerised systems.

The research up to this stage has facilitated the practical allocation of resources. Identifying risk and success factors, prioritising computer systems based on their perceived importance, and optimisation of the risk and success models, resulted in guidelines as to where and on what resources should be used. It reduces the risk of spending excessive resources on wrong factors when trying to minimise risk or maximise success.

The combining of the risk model, success model and importance prioritised list of systems led to the development of a final model with which resources could be allocated to different computer systems (Chapter 7). This final model has the advantage of being an easy and quick method of allocating a percentage of a total budget to a system. Although the model was not tested in an Internal Audit Department it is clear that once management (or internal audit) is in possession of a pre-determined figure it could be used as recommendation as to what should be spent on a system, or it could be used to evaluate already allocated resources. The model does, however, become complicated during the second part of application where costs, to adjust factors, contribute to the complicated nature of this model. The resource allocation model completed the research and should be helpful towards satisfying the last objective as stated in Chapter 1:

To formulate a model which will enable management to optimally allocate resources to different computerised systems based on the importance, risk and success of each computerised system. This model should also be usable as a tool for Internal Auditors to appraise the allocation of resources.

8.4 RECOMMENDATIONS

The research in general, and the conclusions in Paragraph 8.3 have led to recommendations which could be classified as specific or general recommendations.

8.4.1 Specific recommendations

As the main objective of the study was to allocate resources to computerised systems, the following specific recommendations in respect of risk and success factors should be viewed as issues which may need adjustments and therefore will need resources.

- Changes to a system or key personnel should be limited as far as possible. (Change to a system does not refer to maintenance or minor adjustments but rather indicates major changes or enhancements.) These changes are major contributors to the risk of a system.

A recent change in a system may invalidate past performance and usually increases the probability of errors during its initial period of operation.

Systems depend on competent judgements by key personnel and a lack of continuity in personnel may mean less effectiveness.

It remains management's prerogative to decide on how to spend financial resources. However, once an amount is allocated it could be utilised as follows to combat these changes:

* Monetary incentives to retain personnel.
* Acquisition of more sophisticated 'tools' which will enhance personnel morale and thus ensure that they stay with the company.
* Development of new systems which can interface with existing ones, instead of changing old systems (rewrite of systems excluded).

- Management involvement appeared to be crucial for both risk and success of computerised systems. Although difficult to measure or quantify, certain aspects of management (both EDP and User Management) such as manager's support, attitude, competence, integrity, etc. should be dealt with. Spending resources on these issues should ensure a high level of management involvement which in turn will lift success levels and minimise risks.

Once the model has allocated resources to each system, and the intention is to increase management involvement, the following may be considered for spending money on:

* Workshops for managers to acquaint themselves with the different computer systems.
* Ongoing management skills courses.
* Courses for systems development personnel such as presentation skills, communication skills, etc.

The process to get management involvement could be seen as an educating process for both managers and other employees involved. Funds and opportunities must therefore be readily available for this training and educating process.

- Communication between the Data Processing Department and users should be kept at a high level. Lack of communication was found to be one of the major factors influencing the risk of a system.

  There are a number of obvious problems when a communication problem exist. Examples of such problems could be wrong specifications, mis-understanding, low morale, etc.

  To combat these problems, sufficient resources should be made available and possible areas where the resources might be utilised are:

  * Facilities and opportunities to stimulate and enhance communication.
  * General courses such as presentation skills, etc.
  * Specific courses for IS Personnel to understand the "business".

* Software tools and techniques, e.g. prototyping, CASE tools, etc. to simplify procedures.

- The effect that a system has on a user featured as an important issue regarding the success of a system. To maintain a positive, actual and perceived effect, it would be wise to allocate resources in order to:

  * Create a feeling of control by the user. Users should be aware of their power to regulate, direct or dominate the development or alterations to the system which serve their functions.
  * Have a satisfactory amount of specialised instruction and practice to increase the user's proficiency in utilising the computer's capability.
  * Communicate and demonstrate the changes in job freedom and job performance induced by the computer based systems and services.
  * Communicate and demonstrate the degree of involvement and commitment which the user shares with the EDP Staff and others toward the functioning of the computer based system.

- The quality of service from EDP Staff or EDP Centre should be monitored constantly as this was also one of the issues that strongly influenced the success of a computerised system. Resources should be allocated in order to:

  * Keep policies and procedures up to date and fair in respect of time and services allocated to different business units.
  * Develop procedures and techniques to minimise the elapsed time between the user's request for new applications and the design, development and implementation of the system. This also includes the manner, method and required time with which EDP Staff responds to user requests for changes.

- A final specific recommendation is that Internal Audit should review all the above-mentioned recommendations as they all relate directly to the success and risk of computerised systems.

8.4.2 General recommendations

The general recommendations that follow are given specifically to indicate the importance and topicality of the research work pertaining to Internal Auditors.

- All results obtained were based on actual data for actual systems. This implies that, firstly, in our specific organisation they could be used as is without need for further investigation. Secondly, they could be used as a basis for further investigation by any other organisation. A great deal of the initial fieldwork will not be necessary to repeat.

- The models developed were tested and this therefore means that workable scientifically based models are available with which internal auditors may:

  * Verify the reasonableness of already allocated resources.
  * Act as consultants advising on the allocation of resources to different computerised systems based on the observed risk, success and importance issues influencing the systems.

- The models, or parts of models, may be used to decide which systems to audit or how frequently a specific system should be audited. Although not a direct part of the study, this can also be used as an aid to determine how much time should be spent on a project.

- Methods used during the study should be used whenever decisions based on different factors had to be made. This would apply to computer systems as well as any other system/audit. It could therefore be seen as a decision-making tool. The use of this method will be applicable from a macro-level, e.g. drawing-up of an annual audit plan, right through to a micro-level, e.g. determining of risks in one single audit project.

- The techniques used to determine importance of systems are based on a scientifically proven technique. This technique can be used to prioritise virtually anything. Advantages again could be achieved from a macro-level, e.g. prioritising of audit projects for the annual audit plan, to a micro-level, e.g. prioritising of risks or controls in one single system.

A supporting fact for implementation of all the above recommendations is that, although much of the work is based on individuals' judgements, everything is converted to quantitative data which means that it can be numerically measured to make it clear and easy to use.

8.5 FURTHER RESEARCH

Similar completed research projects named various other avenues for further research to be conducted. Some of them have not been satisfactorily addressed and are still valid and very important issues. These issues which also relate to this study and which need further investigation are:

- Determining of a unit cost to adjust a specific factor.
- Costs which do not increase linearly.
- Interdependence among different factors.

Other research projects that originate from this study are:

- The area of experience needs to be expanded. This study was conducted at one organisation and comparable studies at other organisations are necessary to improve and validate the model as a generally accepted model.

- The use of computer power and various productivity tools is generally suggested to enhance productivity of IS Auditors. Research to establish this or a similar model as a generally accepted computerised auditor's tool is necessary. Such studies would include aspects on where and how the model can be incorporated into short to medium term business plans and ultimately into an organisation's long-term strategic plans.

- Interesting research material would be a thorough investigation into the use of artificial intelligence to determine risk and success factors. An application of this (Expert System) to simulate human reasoning in order to prioritise computer systems could also be carried out. Automation of these functions would assist procedural auditors in evaluating computer systems. Apart from assisting non-IS staff it would be an easily usable and reliable tool for anybody who needs to do an assessment of different systems.

BIBLIOGRAPHY

1. **BAILEY, E.K. & PEARSON, S.W.** 1983. Development of a tool for measuring and analysing computer user satisfaction. *Management Science*, 29(5): 530-545, May.

2. **BALAKRISHNAN, R.** 1991. Information acquisition and resource allocation decisions. *The Accounting Review*, 66(1): 120-139, January.

3. **BARRETT, M.J.** 1984. Allocating resources with strength/weakness analysis. *The Internal Auditor*, 43-48, December.

4. **BORITZ, J.E.** 1983. Planning for the internal audit function. Florida : Institute of Internal Auditors Research Foundation.

5. **BRUWER, P.J.S.** 1981. Bydraes tot modelontwikkeling ten einde gerekenarisee-rde stelsels se werkverrigting te evalueer. Potchefstroom : PU vir CHO. (Proefskrif - D.Sc.)

6. **BRUWER, P.J.S.** 1983. Evaluating the performance of computer-based information systems using a restricted linear regression model. *Quaestiones Informaticae*, 2(3): 1-6, September.

7. **BRUWER, P.J.S. & HATTINGH, J.M.** 1985. Constrained regression models for optimisation and forecasting. *ORION*, 1(1): 2-15, May.

8. **BRUWER, P.J.S. & HATTINGH, J.M.** 1986. Models to evaluate the state of computer facilities at South African Universities. *Quaestiones Informaticae*, 4(3): 21-26, October.

9. **BRUWER, P.J.S.** 1987a. User attitudes main reason why information systems fail. *Quaestiones Informaticae*, 5(2): 40-45, October.

10. **BRUWER, P.J.S.** 1987b. Strategic planning models for information systems. *Quaestiones Informaticae*, 5(3): 44-50, December.

11. **BRUWER, P.J.S. & GROENEWALD, J.J.** 1987. A model to evaluate the success of Information centres in organisations. *Quaestiones Informaticae*, 5(3): 24-31, December.

12. **BRUWER, P.J.S.** 1988. Ranking information system problems in a user environment. *Quaestiones Informaticae*, 6(3): 104-108, November.

13. **BRUWER, P.J.S.** 1990a. Kritiese faktore vir die suksesvolle afhandeling van Inligtingstelselprojekte. *Suid-Afrikaanse Rekenaartydskrif*, 3: 19-22, Oktober.

14. **BRUWER, P.J.S.** 1990b. 'n Model vir fasette van strategiese beplanning vir inligtingstelsels in organisasies. *SA Journal of Business Management*, 21(4): 159-162, December.

15. **CARLSON, W. & McNURUN, B.** 1992. Basic principles for measuring IT value. *I/S Analyzer*, 30(10): 1-14, October.

16. **CERULLO, M.J.** 1980. Information Systems success factors, *Journal of Systems Management*, 31(12): 10-19, December.

17. **CHATTERJEE, S. & PRICE, B.** 1977. Regression analysis by example. New York.

18. **CIRTIN, A.** 1982. Risk analysis of internal control procedures. *The Internal Auditor*, 33-35, June.

19. **CURWIN, J. & SLATER, R.** 1991. Quantitative methods for business decisions. 3rd ed. London : Chapman & Hall.

20. **DANTZIG, G.B.** 1972. Linear Programming. London : Addison Wesley.

21. **DAVIS, F.D.** 1989. Perceived usefulness, perceived ease of use, and user acceptance of Information Technology. *MIS Quarterly*, 13(3): 319-335, September.

22. **DE BRABANDER, B. & THIERS, G.** 1984. Successful information system development in relation to situational factors which affect effective communication between MIS-Users and EDP-Specialists. *Management Science*, 30(2): 137-155, February.

23. **DIXON, P.J. & DARWIN, A.J.** 1989. Technology issues facing corporate management in the 1990s. *MIS Quarterly*, 13(3): 247-254, September.

24. **DOLL, W.J.** 1987. Encouraging user management participation in systems design. *Information and Management*, 13(1): 25-32, August.

25. **DOLL, W.J. & TORKZADEH, G.** 1988. The measurement of End-User Computing satisfaction. *MIS Quarterly*, 12(2): 259-272, June.

26. **DOUGHTY, K.** 1993. Disaster recovery planning and business impact. (*In* Umbaugh, R.E., *ed.* Handbook of IS Management: 1993-1994 Yearbook. Boston: Auerbach Publications, Warren Gorham Lamont. p. 333-348.)

27. **DRANG, K.M.** 1985. Information Systems: Does efficiency mean better performance? *Journal of Systems Management*, 36(4): 22-29, April.

28. **DRUMMOND, S.** 1985. Measuring applications development performance. *Datamation*, 31: 102-108.

29. **DUFFY, N.M. & ASSAD, M.G.** 1989. Information Management: Strategy formulation and implementation. Cape Town SA : Oxford University Press.

30. **EMANUEL, P.J.** 1986. An analysis of managerial factors influencing the effectiveness of computer based information systems in South Africa. University of Cape Town : Graduate School of Business. (MBA Research Paper.) November.

31. **FITZGERALD, J. & FITZGERALD, A.F.** 1981. Designing controls into computerised systems. 2nd ed. California : J Fitzgerald and Associates.

32. **FITZGERALD, J.** 1988. Rank-It : A risk assessment tool. California : J Fitzgerald and Associates.

33. **GOODWIN, P.** 1988. Quantitative methods. London : Heinemann Publishing.

34. **HALPER, S.D., DAVIS, G.C., O'NEIL-DUNNE, P.J. & PFAU, P.R.** 1985. Handbook of EDP auditing. Boston : Warren Gorham Lamont.

35. **HALPER, S.D., O'NEIL-DUNNE, P.J. & PARKER, X.L.** 1988. Handbook of EDP auditing: 1988 Cumulative supplement. Boston : Warren Gorham Lamont.

36. **HEAD, R.V.** 1984. Planning techniques for systems management. Massachusetts : QED Information Sciences.

37. **HO, J.K.** 1987. Linear and dynamic programming with Lotus 1-2-3. Oregon: Management Information Source, Inc.

38. **HOWARD, G.S. & RAI, A.** 1993. Adopting technology to improve productivity. (*In* Umbaugh, R.E., *ed.* Handbook of IS Management : 1993-1994 Yearbook. Boston : Auerbach Publications, Warren Gorham Lamont. p.391-400.)

39. **INSTITUTE OF INTERNAL AUDITORS.** 1978. Standards for the Professional Practice of Internal Auditing. Florida : The Institute of Internal Auditors. June.

40. **INSTITUTE OF INTERNAL AUDITORS.** 1991. Systems auditability and control. 12 Modules. Florida : The Institute of Internal Auditors.

41. **INSTITUTE OF INTERNAL AUDITORS.** 1991. Risk Assessment: Statement on Internal Auditing Standards No 9. Florida : The Internal Auditing Standards Board. December.

42. **IVES, B. & OLSON, M.H.** 1984. User involvement and MIS success : A review of research. *Management Science*, 30(5): 586-601, May.

43. **JAMES, P.N.** 1985. Strategic and long-range planning for MIS. (*In* Umbaugh, R.E., *ed.* The handbook of MIS Management. Boston : Auerbach Publications, Warren Gorham Lamont. p.3-13.)

44. **JANSON, M.A.** 1991. Linear regression and information systems: An exploratory study. *Information and Management*, 21(2): 61-72, September.

45. **JONES, L.G.** 1990. Internal Audit Tool Kit. Florida : Institute of Internal Auditors. February.

46. **JORDAAN, D.B.** 1986. Bydraes tot modelontwikkeling ten einde databasis-omgewing te optimaliseer en te evalueer. Potchefstroom : PU vir CHO. (Proefskrif - D.Sc.)

47. **JORDAAN, D.B., HATTINGH, J.M. & STEYN, T.** 1993. Die versoening van konflikterende doelwitte in die databasisomgewing met behulp van regressiemetodes. *Suid-Afrikaanse Rekenaartydskrif*, 10: 32-36, September.

48. **KANTER, H.A., McENROE, J.E. & KYES, M.C.** 1990. Developing and installing an audit risk model. *The Internal Auditor*, 51-55, December.

49. **KERLINGER, F.N.** 1986. Foundations of behavioural research. 3rd ed. New York : CBS Publishing.

50. **KING, W.R. & SABHERWAL, R.** 1992. The factors affecting strategic information systems applications: An empirical assessment. *Information and Management*, 23(4): 217-235, October.

51. **KLEIN, G. & BECK, P.O.** 1987. A decision aid for selecting among information system alternatives. *MIS Quarterly*, 11(2): 177-184, June.

52. **KRCMAR, H. & LUCAS, H.C.** 1991. Success factors for strategic information systems. *Information and Management*, 21(3): 137-145, October.

53. **LAY, P.M.Q.** 1986. A partial-ordering framework for ranking information systems. *De Ratione*, 1: 13-14.

54. **LEDERER, A.L. & MENDELOW, A.L.** 1988. Convincing top management of the strategic potential of information systems. *MIS Quarterly*, 12(4): 525-533, December.

55. **MILLER, J. & DOYLE, B.A.** 1987. Measuring the effectiveness of computer-based Information Systems in the Financial Services Sector. *MIS Quarterly*, 11(1): 107-124, March.

56. **MILLER, J.** 1988. Information Systems Effectiveness: An inter-industry comparison. (*In* Pirow, P., Duffy, N., Ford, J., *eds*. Information Systems in Practice and Theory. p.87-105.)

57. **MILLER, J.** 1989. The effectiveness of computer-based information systems: Definition and Measurement. (Thesis (PhD) - University of Cape Town.)

58. **MILLER, J. & ROSS, M.** 1990. End User Computing: Measuring and achieving success. University of Cape Town : Graduate School of Business. (Working Paper 90-56.) March.

59. **MOLER, C.** 1981. MATLAB User's Guide. University of New Mexico. May.

60. **MILLER, J. & PITT, L.F.** 1990. Top priorities in information systems: The South African perspective. *SA Journal of Business Management*, 21(4): 120-128, December.

61. **MROCH, C.A.** 1987. Practical audit-risk analysis. *The Internal Auditor*, 41-43, August.

62. **MULTINOVICH, J.S. & VLAHOVICH, V.** 1984. A strategy for successful MIS/DSS implementation. *Journal of Systems Management*, 35(8): 8-15, August.

63. **NEUMANN, S., AHITUV, N. & ZVIRAN, M.** 1992. A measure for determining the strategic relevance of IS to the organisation. *Information and Management*, 22(5): 281-299, May.

64. **PALMER, I.C. & POTTER, G.A.** 1989. Computer security risk management. London : Jessica Kingsley.

65. **PALVIA, P. & PALVIA, S.** 1988. The feasibility study in Information Systems: An analysis of criteria and contents. *Information and Management*, 14(5): 211-224, May.

66. **PATTON, J.M., EVANS, J.H. & LEWIS, B.L.** 1983. A framework for evaluating internal audit risk. Florida : Institute of Internal Auditors. (Research Report Number 25.)

67. **PARKER, D.B.** 1981. Managers guide to computer security. Virginia : Reston.

68. **RABINOWITZ, P.** 1968. Application of linear programming to numerical analysis. *SIAM Review*, 10(2): 121-159.

69. **REDELINGHUIS, A., JULYAN, F.W., STEYN, B.L. & BENADE, F.J.C.** 1989. Kwantitatiewe metodes vir bestuursbesluitneming. Durban : Butterworth.

70. **ROCHESTER, J.B. & DOUGLASS, D.P.,** *eds*. 1991. Information Systems: The risk and the return. *I/S Analyzer*, 29(12): 1-12, December.

71. **ROSS, M.P.** 1989. Effectiveness of End User Computing. University of Cape Town : Graduate School of Business. (MBA Research Paper.) December.

72. **RADEMACHER, R.A.** 1989. Critical factors for System Success. *Journal of Systems Management*, 40(6): 15-17, June.

73. **SAATY, T.L.** 1977a. A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology*, 15: 234-281, June.

74. **SAATY, T.L.** 1977b. The Sudan Transport Study. *Interfaces*, 8(1): 37-57, November.

75. **SAATY, T.L. & BENNETT, J.P.** 1977. A theory of analytical hierarchies applied to political candidacy. *Behavioral Science*, 22: 237-245, July.

76. **SAATY, T.L.** 1980. The Analytic Hierarchy Process. USA : McGraw-Hill.

77. **SANDERS, D.H.** 1988. Computers Today. 3rd ed. Singapore : McGraw-Hill.

78. **SAS/STAT USER'S GUIDE.** 1990. Volume 2 Version 6. Fourth Edition. North Carolina : SAS Institute Inc.

79. **SCHUMANN, D.E.W., BOUWER, B. & SCHOEMAN, H.S.** 1974. Elementêre statistiek : Beskrywende metodes. Suid-Afrika : McGraw-Hill Boekmaatskappy.

80. **SCUDDER, R.A. & KUCIC, A.R.** 1991. Productivity measures for information systems. *Information and Management*, 20(5): 343-354, May.

81. **SELIG, F.F.** 1991. Managing information technology in the nineties. *Information and Management*, 21(5): 251-255, December.

82. **SENN, J.A.** 1980. Management's assessment of Computer Information Systems. *Journal of Systems Management*, 31(9): 6-11, September.

83. **STANLEY, E.J.D.** 1987. Strategic success factors of information systems projects in financial institutions. Johannesburg : University of Witwatersrand. (Research report - MBA.)

84. **STEYN, A.G.W., SMIT, C.F. & DU TOIT, S.H.C.** 1984. Moderne statistiek vir die praktyk. Pretoria : J L van Schaik.

85. **SINGLETON, J.P., McLEAN, E.R. & ALTMAN, E.N.** 1988. Measuring Information Systems Performance : Experience with the management by results system at Security Pacific Bank. *MIS Quarterly*, 12(2): 325-336, June.

86. **STRAUB, D.W.** 1989. Validating instruments in MIS Research. *MIS Quarterly*, 13(2): 147-160, June.

87. **UMBAUGH, R.E.** 1985. Improving MIS Productivity. (*In* Umbaugh, R.E., *ed.* The handbook of MIS Management. Boston : Auerbach Publications, Warren Gorham Lamont. p.745-759.)

88. **UMBAUGH, R.E.** 1992. Developing an Information Technology resource plan. (*In* Umbaugh, R.E., *ed.* Handbook of IS Management : 1992-1993 Yearbook. Boston : Auerbach Publications, Warren Gorham Lamont. p.13-28.)

89. **URBANIC, F.R.** 1993. Planning : The risk assessment approach to internal audit scheduling. *Internal Auditing*, 9(1): 88-95, Summer.

90. **UYS, J.** 1992. Quattro Pro: A user's guide. Versions 3 & 4. Stellenbosch: Helderberg Publishers.

91. **UDO, G.J. & DAVIS, J.S.** 1992. Factors affecting decision support system benefits. *Information and Management*, 23(6): 359-371, December.

92. **VALLABHANENI, S.R.** 1989. Auditing computer security: A manual with case studies. New York : John Wiley.

93. **WALLS, J. & TURBAN, E.** 1991. Information Centre Management Control Measures: A survey and comparison. *IEEE Transactions on Engineering Management*, 38(4): 336-343, November.

94. **WALZ, A.P.** 1991. An integrated risk model. *Internal Auditor*. Journal of the Institute of Internal Auditors, 60-65, April.

95. **WHITEHEAD, P. & WHITEHEAD, G.** 1992. Statistics for Business. 2nd ed. London : Pitman.

96. **WILLEMSE, I.** 1990. Statistical methods and financial calculations. Cape Town : Juta & Co.

97. **YAVERBAUM, G.J.** 1988. Critical factors in the User Environment: An experimental study of users, organisations and tasks. *MIS Quarterly*, 12(1): 75-87, March.

AFRIKAANSE OPSOMMING

INLEIDING

Literatuurstudies toon aan dat die beplanning vir rekenaarbronne gewoonlik die voorsiening van toerusting, programmatuur, personeel en fasiliteite insluit. Die toekenning van finansiële bronne aan verskillende stelsels (om genoemde fisiese behoeftes te bevredig) is egter nie geredelik beskikbaar nie.

Die leser moet in ag neem dat die studie gedoen is vanuit 'n Interne Oudit oogpunt aangesien die skrywer in diens van 'n groot organisasie is as Rekenaarouditeur. Die Standaarde vir die Professionele Praktyk van Interne Oudit verwys direk na die ekonomiese en effektiewe gebruik van bronne as deel van die omvang van 'n Interne Ouditeur se pligte. Hierdie bronne sluit alle bronne in wat nodig is vir die suksesvolle bedryf van 'n organisasie. Die bronne, ontplooi in 'n rekenaaromgewing, is dus ook onderhewig aan die evaluering van Interne Ouditeure.

In die lig van hierdie inleidende paragrawe kan dus gesê word dat die studie geïnisieer is deur, eerstens, die feit dat bestuur van 'n onderneming 'n betroubare bronverdelingstrategie vereis en tweedens dat Interne Oudit 'n tegniek benodig om die toekenning van bronne aan verskillende rekenaarstelsels te evalueer. Die studie poog om 'n strategiese hulpmiddel te skep waarvolgens finansiële bronverdelings aan verskillende rekenaarstelsels gedoen kan word, gebaseer op die stelsel se waargenome belangrikheid, sukses en risiko.

DOEL VAN DIE STUDIE

Spesifieke doelwitte kan as volg opgesom word:

- Bepaling van faktore wat die meeste bydra tot:
  * risiko van 'n rekenaarstelsel
  * sukses van 'n rekenaarstelsel

- Prioritisering van rekenaarstelsels op grond van hul waargenome belangrikheid.-

- Bepaling van, m.b.v. optimiseringstegnieke, die belangrikste faktore wat verstel moet word om sukses te maksimeer en risiko te minimaliseer.

- Die formulering van 'n model wat bestuur in staat sal stel om op optimale wyse finansiële bronne toe te ken aan verskillende rekenaarstelsels. Hierdie model moet ook bruikbaar wees as 'n tegniek vir Interne Ouditeure om bronverdelings te verifieer. Die model moet verder gebaseer wees op die belangrikheid, sukses en risiko van 'n stelsel.

HIPOTETIESE NAVORSINGSMODEL

Ten opsigte van risiko en sukses is van beskrywende modelle gebruik gemaak. Met behulp van SAS-programmatuur, korrelasie- en regressiemetodes is ondersoek ingestel na die lineêre verwantskappe tussen sekere veranderlikes en die risiko of sukses van 'n stelsel.

Die maatstaf vir risiko was gebaseer op die gemiddelde evaluerings van senior dataverwerkingspersoneel, gebruikers en 'n onafhanklike konsultant. Sukses se maatstaf is afgelei van die gemiddelde evaluerings deur senior dataverwerkingspersoneel en gebruikers.

Die model om stelsels te prioritiseer is ontleen aan 'n metode deur T Saaty ontwikkel. Dit behels die vergelyking van alle stelsels in pare. 'n Matriks, waarvan die inskrywings 'n individu se skatting is van die relatiewe dominansie van een stelsel bo 'n ander, is opgestel. Die genormaliseerde eievektor, geassosieer met die grootste eiewaarde van die matriks, verskaf dan 'n skaal van waargenome belangrikheid.

INSAMELING VAN DATA

Ten einde die verwantskappe tussen die verskillende veranderlikes te bepaal is data m.b.t. risiko en sukses verkry vanaf senior dataverwerkingspersoneel, gebruikers en 'n konsultant. Hierdie data is ingesamel m.b.v. vraelyste en is gedoen vir 'n totaal van 36 verskillende gerekenariseerde stelsels.

Die graad van belangrikheid van 'n spesifieke stelsel is verkry deurdat senior dataverwerkingspersoneel en 'n gebruiker die stelsels in pare vergelyk het. Volgens 'n numeriese skaal is dan (vir elke 2 stelsels) die graad van belangrikheid van elke stelsel t.o.v. elke ander stelsel aangedui. Hierdie oefening is uitgevoer vir al 36 verskillende stelsels en het as resultaat 'n volledige kwantifiseerbare prioriteitslys van die 36 stelsels onder beskouing gelewer.

Dit is belangrik dat die leser in gedagte moet hou dat die navorsing by **een** spesifieke organisasie gedoen is. Faktore, prioritisering van stelsels en data wat gebruik is om modelle te ontwikkel is dus spesifiek aan hierdie organisasie. Tegnieke en modelle wat ontwikkel is kan egter by enige organisasie toegepas word.

VERWANTSKAPPE WAT BESTUDEER IS

Lineêre regressie en korrelasie het aangetoon dat die volgende verwantskappe bestaan:

- Verwantskappe tussen risiko en
  - F_1 - Profielrisiko gebaseer op staatveranderlikes
  - F_2 - Fisiese sekuriteit
  - F_3 - Tegnologie
  - F_4 - Opleiding van dataverwerkingspersoneel
  - F_5 - Onlangse verandering aan stelsel of sleutelpersoneel
  - F_6 - Bestuur se betrokkenheid
  - F_7 - Kommunikasie tussen dataverwerkingsdepartement en gebruikers
  - F_8 - Logiese sekuriteit en kwaliteit van interne kontroles

- Verwantskappe tussen sukses en
  - X_1 - Bestuur se betrokkenheid
  - X_2 - Verhouding tussen dataverwerkingspersoneel en gebruikers
  - X_3 - Kwaliteit van dataverwerkingspersoneel
  - X_4 - Funksionele siening/posisie van dataverwerkingsdepartement
  - X_5 - Eienskappe van stelselafvoer
  - X_6 - Effek van stelsel op gebruikers
  - X_7 - Konvensionele stelseleienskappe
  - X_8 - Kwaliteit van diens gelewer deur dataverwerkingsdepartement/personeel

DIE LINEÊRE REGRESSIEMODELLE

Deur gebruik te maak van stapsgewyse lineêre regressie is 'n "beste" deelversameling van onafhanklike veranderlikes vir beide risiko en sukses bepaal.

Ten opsigte van risiko is die onafhanklike veranderlikes van 8 na 6 verminder wat steeds 94% (beste was 94,9%) van die variasie in risiko verduidelik. Vir sukses is die aantal onafhanklike veranderlikes ook van 8 na 6 verminder wat 92% (beste was 93,2%) van die variasie in sukses verduidelik.

Die lineêre regressies wat verkry was, was as volg:

Risiko = $3,3961 + 0,3440F_1 - 0,1018F_2 - 0,1345F_3 + 0,1976F_5 - 0,1869F_6 - 0,1316F_7$

F-Toets : 72,28 met waarskynlikheid > F 0,0001

Sukses = $0,9926 + 0,1464X_1 + 0,1536X_4 + 0,1163X_5 + 0,1305X_6 + 0,1595X_7 + 0,1583X_8$

F-Toets : 58,89 met waarskynlikheid > F 0,0001

Die invloed van 'n spesifieke onafhanklike veranderlike op 'n afhanklike veranderlike (risiko of sukses) is vervolgens ondersoek deur gebruik van 'n metode voorgestel deur *Bruwer en Hattingh*.

Vir elk van die bogenoemde lineêre regressievergelykings is 'n lineêre programmeringsprobleem geformuleer en opgelos terwyl elk van die beslissingsveranderlikes om die beurt beperk is tot die waardes 1, 2, ..., 7. Hierdie oplossings gee dan die maksimum/minimum (vir Sukses en Risiko) sowel as die vlakke van die ander beslissingsveranderlikes by hierdie optimale oplossing. Grafiese voorstellings is verkry waarop die invloed van elke onafhanklike veranderlike duidelik waarneembaar was.

'n Addisionele voordeel van hierdie tegniek is dat faktore wat 'n besonder betekenisvolle bydrae tot risiko of sukses vlakke lewer, relatief maklik geïdentifiseer kan word.

Die volgende faktore is as besonder betekenisvol geïdentifiseer:

Risiko	-	Onlangse veranderinge aan stelsel of sleutelpersoneel
	-	Bestuur se betrokkenheid
	-	Kommunikasie tussen dataverwerkingsdepartement en gebruikers
Sukses	-	Bestuur se betrokkenheid
	-	Effek van stelsel op gebruikers
	-	Kwaliteit van diens gelewer deur dataverwerkingsdepartement/personeel

'n MODEL OM KONFLIKTERENDE FAKTORE TE VERSOEN

Die lys van faktore wat vir sukses en risiko geïdentifiseer is was interafhanklik en in baie gevalle selfs in konflik met mekaar. 'n Model wat voorsiening sou maak vir hierdie teenstrydighede is toe geformuleer en het basies die volgende behels:

- Bepaling van lineêre regressievergelykings wat **beide** sukses en risiko se faktore in ag neem.

  Die vergelykings verkry was as volg:

$$\text{Sukses} = 1{,}0052 - 0{,}0409F_1 - 0{,}0586F_2 - 0{,}0016F_3 + 0{,}0448F_4 + 0{,}0713F_5 + 0{,}1854F_6 - 0{,}1164F_7 + 0{,}0674F_8 - 0{,}0452X_1 + 0{,}0337X_2 + 0{,}0732X_3 + 0{,}2042X_4 + 0{,}1668X_5 + 0{,}1522X_6 + 0{,}1638X_7$$

met $R^2 = 0{,}95$

en die F-Toets: 26,83 met waarskynlikheid > F 0,0001

$$\text{Risiko} = 3{,}2252 + 0{,}3354F_1 - 0{,}0627F_2 - 0{,}0945F_3 + 0{,}0599F_4 + 0{,}2092F_5 - 0{,}1801F_6 - 0{,}1387F_7 - 0{,}0289F_8 + 0{,}0191X_1 - 0{,}0537X_2 + 0{,}0313X_3 + 0{,}0413X_4 - 0{,}0075X_5 - 0{,}0473X_6 - 0{,}0509X_7$$

met $R^2 = 0{,}96$

en die F-Toets: 33,36 met waarskynlikheid > F 0,0001

F_i = Risikofaktore

X_i = Suksesfaktore

- Formuleer 'n lineêre programmeringsprobleem, soortgelyk aan die oorspronklike risiko- en suksesprobleme, met die addisionele beperking van die Risiko lineêre regressievergelyking wat tot sekere vlakke beperk word.

Hierdie model het die voordeel gehad dat beide sukses- en risikofaktore in ag geneem is om konflikterende doelwitte uit te skakel. Dit het verder 'n ingeboude meganisme wat verseker dat risiko onder voorafbepaalde vlakke bly.

MODELLE VIR DIE TOEKENNING VAN BRONNE

Kostemodel

Indien eenheidskostes $C_1, C_2, \ldots, C_n$ beskikbaar sou wees om veranderlikes $X_1, X_2, \ldots, X_n$ te verstel dan kan die volgende kostebeperking ook in die lineêre programmeringsprobleem geïnkorporeer word:

$$C_1X_1 + C_2X_2 + \ldots + C_nX_n \leq M \text{ waar M die totale beskikbare fondse is}$$

'n Tegniek om hierdie verskillende C_i-waardes te bepaal is voorgestel en indien dit sou realiseer dan beteken dit dat vir elke spesifieke stelsel die volgende beperking ook in berekening gebring kan word:

$$| e_1^* - e_1 | C_1 + | e_2^* - e_2 | C_2 + \ldots + | e_n^* - e_n | C_n \leq T_{Ri}$$

waar

e_j - gegewe evaluering van faktore j is;

e_j^* - verlangde vlak van faktor j is;

C_j - koste om faktor j met een eenheid te verander; en

T_{Ri} - totale finansiële bronne beskikbaar vir stelsel i.

DIREKTE TOEDELING VAN BRONNE AAN SPESIFIEKE STELSELS

'n Model is voorgestel om direk 'n persentasie toekenning, gebaseer op risiko, sukses en belangrikheid van die stelsel, aan spesifieke stelsels te maak. Hierdie model neem die drie belangrike aspekte (sukses, risiko, belangrikheid), soos tydens die doelwitformulering van die studie, in ag. Afvoer van hierdie model kan dus beskou word as voldoende hulpmiddel vir die toekenning van bronne of dit kan gebruik word vir die bepaling van T_{Ri} in die vorige paragraaf.

Die model is as volg geformuleer:

$$T_{Ri} = I_i[\alpha\delta_{Si} + \beta\delta_{Ri}]$$

waar

* T_{Ri} is totale bronne vir stelsel i;
* I_i is die waargenome belangrikheid van stelsel i;
* α is 'n gewig geassosieer met die belangrikheid van die sukses van 'n stelsel; en
* β is 'n gewig geassosieer met die belangrikheid van die risiko van 'n stelsel.

* $\delta_{Si} = \begin{cases} 0 \text{ as } S_i \geq S^* \\ S^* - S_i \text{ as } S_i < S^* \end{cases}$ S_i = Huidige suksesvlak vir stelsel i; S^* = Verlangde minimum sukses vlak vir alle stelsels

* $\delta_{Ri} = \begin{cases} 0 \text{ as } R_i \leq R^* \\ R_i - R^* \text{ as } R_i > R^* \end{cases}$ R_i = Huidige risiko vlak vir stelsel i; R^* = Verlangde maksimum risiko vlak vir alle stelsels

OPSOMMING

Die navorsing het aangetoon dat daar spesifieke faktore is wat 'n betekenisvolle impak op die risiko- en suksesvlakke van gerekenariseerde stelsels sal hê. Deur middel van 'n optimeringstegniek is bepaal watter faktore die meeste invloed sal hê by die bepaling van risiko en sukses.

'n Tegniek waarvolgens stelsels geprioritiseer is op grond van hul waargenome belangrikheid het tot gevolg gehad dat 'n lys van stelsels, in volgorde van belangrikheid, opgestel kon word.

Die kombinering van al hierdie inligting en modelle het gelei tot 'n finale voorgestelde model om bronne mee te verdeel. Hierdie model, wat die uiteindelike doelwit van die studie bevredig, kan aangewend word om reeds toegekende bronne te verifieer of om aanbevelings te maak wanneer nuwe toedelings gedoen moet word.

APPENDIX A

SUCCESS FACTORS:

F_1	-	Top management involvement
F_2	-	EDP Staff/User relationship
F_3	-	EDP Staff quality
F_4	-	EDP Centre/Function
F_5	-	System output characteristics
F_6	-	Effect of system on users
F_7	-	Issues concerning conventional system characteristics
F_8	-	Quality of service from EDP Staff/Centre

APPENDIX B

RISK FACTORS:

OldRisk	-	Risk based on state variables
F_1	-	Physical security
F_2	-	Technology used
F_3	-	Training of EDP Personnel
F_4	-	Recent changes to system or key personnel
F_5	-	Management involvement
F_6	-	Communication between DP and users
F_7	-	Logical security and internal controls

APPENDIX C

	SUCCESS	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8
1	5	1	2	4	6	6	2	5	6
2	6	5	7	6	6	7	5	7	6
3	6	6	6	5	6	7	4	6	5
4	6	7	6	6	6	7	5	5	6
5	5	4	4	5	5	7	5	6	4
6	6	7	5	6	6	7	5	6	7
7	4	4	5	4	5	3	5	4	2
8	6	6	6	5	6	7	6	5	6
9	6	4	5	4	6	6	5	6	6
10	4	6	4	4	3	3	3	2	4
11	6	6	6	5	5	5	7	6	6
12	5	3	6	4	4	5	7	5	5
13	6	6	5	6	5	5	7	6	5
14	6	6	6	6	6	6	6	6	6
15	3	2	5	2	2	2	1	3	3
16	5	6	5	4	6	6	6	3	3
17	4	2	5	2	4	4	5	2	2
18	5	2	3	3	4	6	6	4	3
19	6	6	5	5	6	6	7	4	6
20	6	6	5	3	6	6	7	4	6
21	4	4	3	3	5	4	1	3	5
22	5	2	5	2	6	6	7	5	6
23	5	6	6	6	5	5	4	3	5
24	7	6	6	6	6	7	7	7	7
25	6	6	4	6	6	5	5	5	4
26	7	6	6	6	6	7	6	6	6
27	5	6	6	6	4	5	4	2	6
28	4	2	4	4	5	2	1	3	6
29	5	3	5	6	5	5	4	4	7
30	5	3	4	5	5	4	4	4	5
31	3	2	6	4	2	2	2	3	1
32	5	5	5	4	4	4	7	5	3
33	2	1	5	3	2	2	2	2	2
34	5	6	6	4	5	4	4	5	5
35	4	3	5	4	5	5	4	4	3
36	5	6	5	5	5	5	4	3	4

APPENDIX D

	RISK	OLD RISK	F_1	F_2	F_3	F_4	F_5	F_6	F7
1	3,5	2,75	6	4	1	5	1	3	4
2	3,5	5,25	6	7	2	7	5	6	6
3	2,5	6	7	4	3	1	6	5	5
4	2	5,25	7	4	4	1	7	7	6
5	2,5	4	6	4	2	1	4	3	5
6	1,5	4,25	7	4	4	1	7	6	5
7	2	2	6	4	2	1	4	3	4
8	2	3,75	6	4	3	1	6	5	5
9	3	2,25	3	2	6	4	4	5	3
10	2	2,25	5	3	5	1	6	4	5
11	2	5,25	6	6	5	2	6	6	5
12	3	4,75	4	5	4	2	3	5	4
13	2,5	5,25	5	5	5	2	6	5	5
14	3	5,75	6	4	3	5	6	7	6
15	3	3	3	5	2	1	2	1	2
16	3	6	3	4	4	2	6	6	6
17	3	2,25	4	3	1	1	2	2	4
18	4	4,5	6	4	3	6	2	6	6
19	3,5	6	6	4	5	5	6	5	6
20	3,5	5,5	6	4	3	5	6	5	6
21	1,5	1	6	6	6	1	4	5	6
22	3,5	6,5	6	6	1	2	2	6	6
23	2,5	4	6	4	6	2	6	5	4
24	2	4,5	6	6	6	1	6	6	6
25	3	4,5	5	6	4	5	6	4	5
26	2,5	5	6	4	4	5	6	6	6
27	2	3,5	6	4	3	3	6	6	6
28	3	2,25	6	6	1	6	2	2	7
29	2,5	3,25	4	5	1	1	3	3	5
30	3,5	3,25	4	5	1	6	3	3	5
31	5,5	6,5	5	5	6	7	2	3	6
32	4	6	6	2	3	5	5	6	5
33	3,5	2,25	5	3	3	6	1	5	2
34	3,5	6	5	6	4	3	6	3	3
35	3	2,25	4	2	2	2	3	3	3
36	2	2	4	2	3	1	6	5	3

APPENDIX E

A. EVALUATION OF THE SYSTEM'S ATTRIBUTES (CASE STUDY)

FACTORS	LOW/OLD/ BAD			AVERAGE			HIGH/NEW/ EXCELLENT
1. Top Management Involvement	1	2	3	4	5	6	7
2. EDP Staff/User Relationship etc.	1	2	3	4	5	6	7
3. EDP Staff Quality	1	2	3	4	5	6	7
4. EDP Centre/Function	1	2	3	4	5	6	7
5. System Output Characteristics	1	2	3	4	5	6	7
6. Effect of System on Users	1	2	3	4	5	6	7
7. Issues concerning conventional system characteristics	1	2	3	4	5	6	7
8. Quality of service from EDP Staff/Centre	1	2	3	4	5	6	7

B. SUCCESS OF THE SYSTEM, BASED ON THE ABOVE EIGHT ATTRIBUTES:

	LOW			MEDIUM			HIGH
SUCCESS	1	2	3	4	5	6	7

APPENDIX F

THE FOLLOWING INFORMATION IS GIVEN:

A. EVALUATION OF THE SYSTEM'S ATTRIBUTES (CASE STUDY)

	FACTORS	LOW/OLD/ BAD			AVERAGE			HIGH/NEW/ EXCELLENT
1.	Integration with and impact on other systems	1	2	3	4	5	6	7
2.	Influence of Acts of God (Natural Disasters) e.g. lightning, earthquakes, fires, etc. on this system.	1	2	3	4	5	6	7
3.	Influence of change in Government regulations (e.g. VAT), union policies, company policies, etc. on this system.	1	2	3	4	5	6	7
4.	The degree of dependence on external sources e.g. vendor support, international standards, Post & Telecom, quality of products purchased etc. for this system.	1	2	3	4	5	6	7
5.	The system's relationship with personnel issues e.g strikes, industrial relations, deliberate actions (e.g. vandalism), epidemic diseases etc.	1	2	3	4	5	6	7
6.	The criticality of the period when the system has to be operational e.g. daily, monthly, 24 hours a day etc.	1	2	3	4	5	6	7
7.	The degree to which the system is linked to valuable assets and operates on sensitive data and future action by management may also be heavily dependent upon the information produced by this system.	1	2	3	4	5	6	7

B. RISK OF THE SYSTEM, BASED ON THE ABOVE SEVEN ATTRIBUTES:

	LOW			MEDIUM			HIGH
RISK	1	2	3	4	5	6	7

C. CONSIDER THE FOLLOWING GIVEN DEGREES OF PROVISIONS WHICH WERE MADE IN AN ATTEMPT TO KEEP THE RISK OF THE SYSTEM UNDER CONTROL

FACTORS		LOW/OLD/ BAD			AVERAGE			HIGH/NEW/ EXCELLENT
1.	Physical security	1	2	3	4	5	6	7
2.	Technology used	1	2	3	4	5	6	7
3.	Training EDP Personnel have undergone or are at present receiving (including continuous)	1	2	3	4	5	6	7
4.	Recent changes to system or key personnel	1	2	3	4	5	6	7
5.	How managers (EDP and Users) act, e.g. support attitude, etc.	1	2	3	4	5	6	7
6.	Communication between DP Department and Users	1	2	3	4	5	6	7
7.	Logical security and quality of internal controls	1	2	3	4	5	6	7

D. BASED ON THE ABOVE DEGREE OF CONTROLS, PROVISIONS MADE, ETC, PLEASE GIVE A NEW RISK EVALUATION:

	LOW			MEDIUM			HIGH
RISK	1	2	3	4	5	6	7

APPENDIX G

FACTORS, THEIR DEFINITIONS AND ADJECTIVE PAIRS (*BAILEY-PEARSON*)

1. *TOP MANAGEMENT INVOLVEMENT*

The positive or negative degree of interest, enthusiasm, support or participation of any management level above the user's own level toward computer-based information systems or services or toward the computer staff which support them:

strong vs weak
consistent vs bad
good vs bad
significant vs insignificant

2. *ORGANISATIONAL COMPETITION WITH THE EDP UNIT*

The contention between the respondent's organisational unit and the EDP unit when vying for organisational resources or for responsibility for success or failure of computer-based information systems or services of interest to both parties:

productive vs destructive
rational vs emotional
low vs high
harmonious vs dissonant

3. *PRIORITIES DETERMINATION*

Policies and procedures which establish precedence for the allocation of EDP resources and services between different organisational units and their requests:

fair vs unfair
consistent vs inconsistent
just vs unjust
precise vs vague

4. *CHARGE-BACK METHOD OF PAYMENT FOR SERVICES*

The schedule of charges and the procedures for assessing users on a pro rata basis for the EDP resources and services that they utilise.

just vs unjust
reasonable vs unreasonable
consistent vs inconsistent
known vs unknown

5. *RELATIONSHIP WITH THE EDP STAFF*

The matter and methods of interaction, conduct and association between the user and the EDP staff.

harmonious vs dissonant
good vs bad
cooperative vs uncooperative
candid vs deceitful

6. *COMMUNICATION WITH THE EDP STAFF*

The manner and methods of information exchange between the user and the EDP staff.

harmonious vs dissonant
productive vs destructive
precise vs vague
meaningful vs meaningless

7. *TECHNICAL COMPETENCE OF THE EDP STAFF*

The computer technology skills and expertise exhibited by the EDP staff.

current vs obsolete
sufficient vs insufficient
superior vs inferior
high vs low

8. ATTITUDE OF THE EDP STAFF

The willingness and commitment of the EDP staff to subjugate external, professional goals in favour of organisationally directed goals and tasks.

user-oriented vs self-centred
cooperative vs belligerent
courteous vs discourteous
positive vs negative

9. SCHEDULE OF PRODUCTS AND SERVICES

The EDP centre timetable for production of information system outputs and for provision of computer-based services.

good vs bad
regular vs irregular
reasonable vs unreasonable
acceptable vs unacceptable

10. TIME REQUIRED FOR NEW DEVELOPMENT

The elapsed time between the user's request for new applications and the design, development and/or implementation of the application systems by the EDP staff.

short vs long
dependable vs undependable
reasonable vs unreasonable
acceptable vs unacceptable

11. PROCESSING OF CHANGE REQUESTS

The manner, method and required time with which the EDP staff responds to user requests for changes in existing computer-based information systems of services.

fast vs slow
timely vs untimely
simply vs complex
flexible vs rigid

12. VENDOR SUPPORT

The type and quality of the service rendered by a vendor, either directly or indirectly, to the user to maintain the hardware or software required by that organisational status.

skilled vs bungling
sufficient vs insufficient
eager vs indifferent
consistent vs inconsistent

13. RESPONSE/TURNAROUND TIME

The elapsed time between a user-initiated request for service or action and a reply to that request. Response time generally refers to the elapsed time for terminal type request or entry. Turnaround time generally refers to the elapsed time for execution of a program submitted or requested by a user and the return of the output to that user:

fast vs slow
good vs bad
consistent vs inconsistent
reasonable vs unreasonable

14. MEANS OF INPUT/OUTPUT WITH EDP CENTRE

The method and medium by which a user inputs data to and receives output from the EDP centre:

convenient vs inconvenient
clear vs hazy
efficient vs inefficient
organised vs disorganised

15. CONVENIENCE OF ACCESS

The ease or difficulty with which the user may act to utilise the capability of the computer system:

convenient vs inconvenient
good vs bad
easy vs difficult
efficient vs inefficient

16. ACCURACY

The correctness of the output information:

accurate vs inaccurate
high vs low
consistent vs inconsistent
sufficient vs insufficient

17. TIMELINESS

The availability of the output information at a time suitable for its use:

timely vs untimely
reasonable vs unreasonable
consistent vs inconsistent
punctual vs tardy

18. PRECISION

The variability of the output information from that which it purports to measure:

sufficient vs insufficient
consistent vs inconsistent
high vs low
definite vs uncertain

19. RELIABILITY

The consistency and dependability of the output information:

consistent vs inconsistent
high vs low
superior vs inferior
sufficient vs insufficient

20. CURRENCY

The age of the output information:

good vs bad
timely vs untimely
adequate vs inadequate
reasonable vs unreasonable

21. COMPLETENESS

The comprehensiveness of the output information content:

complete vs incomplete
consistent vs inconsistent
sufficient vs insufficient
adequate vs inadequate

22. FORMAT OF OUTPUT

The material design of the layout and display of the output contents:

good vs bad
simple vs complex
readable vs unreadable
useful vs useless

23. LANGUAGE

The set of vocabulary, syntax and grammatical rules used to interact with the computer systems:

simple vs complex
powerful vs weak
easy vs difficult
easy-to-use vs hard-to-use

24. VOLUME OF OUTPUT

The amount of information conveyed to a user from computer-based systems. This is expressed not only by the number of reports or outputs but also by the voluminousness of the output contents:

concise vs redundant
sufficient vs insufficient
necessary vs unnecessary
reasonable vs unreasonable

25. RELEVANCY

The degree of congruence between what the user wants or requires and what is provided by the information products and services:

useful vs useless
relevant vs irrelevant
clear vs hazy
good vs bad

26. ERROR RECOVERY

The methods and policies governing correction and re-run of system outputs that are incorrect:

fast vs slow
superior vs inferior
complete vs incomplete
simple vs complex

27. SECURITY OF DATA

The safeguarding of data from misappropriation or unauthorised alteration or loss:

secure vs insecure
good vs bad
definite vs uncertain
complete vs incomplete

28. DOCUMENTATION

The recorded description of an information system. This includes formal instructions for the utilisation of the system:

clear vs hazy
available vs unavailable
complete vs incomplete
current vs obsolete

29. EXPECTATIONS

The set of attributes or features of the computer-based information products or services that a user considers reasonable and due from the computer-based information support rendered within his organisation:

pleased vs displeased
high vs low
definite vs uncertain
optimistic vs pessimistic

30. UNDERSTANDING OF SYSTEMS

The degree of comprehension that a user possesses about the computer-based information systems or services that are provided:

high vs low
sufficient vs insufficient
complete vs incomplete
easy vs hard

31. PERCEIVED UTILITY

The user's judgement about the relative balance between the cost and the considered usefulness of the computer-based information products or services that are provided. The costs include any costs related to providing the resource, including money, time, manpower and opportunity. The usefulness includes any benefits that the user believes to be derived from the support:

high vs low
positive vs negative
sufficient vs uncertain
good vs bad

32. CONFIDENCE IN THE SYSTEMS

The user's feelings of assurance or certainty about the systems provided:

high vs low
strong vs weak
definite vs uncertain
good vs bad

33. FEELING OF PARTICIPATION

The degree of involvement and commitment which the user shares with the EDP staff and others toward the functioning of the computer-based information systems and services:

positive vs negative
encouraged vs repelled
sufficient vs insufficient
involved vs uninvolved

34. *FEELING OF CONTROL*

The user's awareness of the personal power or lack of power to regulate, direct or dominate the development, alteration and/or execution of the computer-based information systems or services which serve the user's perceived function:

high vs low
sufficient vs insufficient
precise vs vague
strong vs weak

35. *DEGREE OF TRAINING*

The amount of specialised instruction and practice that is afforded to the user to increase the user's proficiency in utilising the computer capability that is unavailable:

complete vs incomplete
sufficient vs insufficient
high vs low
superior vs inferior

36. *JOB EFFECTS*

The changes in job freedom and job performance that are ascertained by the user as resulting from modifications induced by the computer-based information systems and services:

liberating vs inhibiting
significant vs insignificant
good vs bad
valuable vs worthless

37. ORGANISATIONAL POSITION OF THE EDP FUNCTION

The hierarchical relationship of the EDP function to the overall organisational structure:

appropriate vs inappropriate
strong vs weak
clear vs hazy
progressive vs regressive

38. FLEXIBILITY OF SYSTEMS

The capacity of the information system to change or to adjust in response to new conditions, demands or circumstances:

flexible vs rigid
versatile vs limited
sufficient vs insufficient
high vs low

39. INTEGRATION OF SYSTEMS

The ability of systems to communicate/transmit data between systems servicing different functional areas:

complete vs incomplete
sufficient vs insufficient
successful vs unsuccessful
good vs bad