STRATEGIC ASPECTS IN INVESTMENT DECISION-MAKING

by

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submitted in fulfilment of the requirements for the degree

of

MASTER OF COMMERCE

in the subject

BUSINESS MANAGEMENT

at the

UNIVERSITY OF SOUTH AFRICA

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NOVEMBER 1997
ACKNOWLEDGEMENTS

I wish to express my sincere thanks to all who assisted me in the process of researching the subject contained in this report.

In particular:

* Professor Egbert Begemann, for assisting me through his role as my supervisor and for editing this work.

* Mrs Bera Kemp, Mrs Louise Venter and Mrs Labuschagne, for the statistical analysis of the questionnaire data.

* Mrs Linda Parkes for the formatting, lay-out and assistance.

* Mr Charles Bangudi, Ms Yvonne Gibson, Mr Nelson Luntadila, Mr Robert Mansueki, Mr Roger Mukassa and Mr Lunda Yamba, Mr Bernard Munyai, and Mr Jabu Sikonde, for assistance and encouragement.

* My parents: mother and father, and my brothers and sisters for their support and vision.

* My sister Mamie Diazola to whom this work is dedicated.

* Ms Veronique Lukeba Nkanza, my fiancee, for her patience and understanding.

* Our God Father, Who makes all things possible.
SYNOPSIS

The major concern of investment decision-makers is to find the appropriate capital budgeting techniques to apply. Many factors cause change within an organisation. Strategic investment management takes a close look at these changing factors.

To this end, a literature study of popular capital budgeting procedures, investment strategic theory, and a selected method for linking the two was undertaken. A sample of manufacturers in the Gauteng region of South Africa was chosen to indicate whether there is a correlation between financial theory and practice.

The results of this survey indicated that financial evaluation was widely practised. Whereas, strategic analysis was used less often.

The need for an in-depth study of other economic sectors and the financial theory and practice used by the investment decision-makers in those sectors is identified as a possible future study. The value inherent in the evaluation of relative performances of manufacturing firms, which have applied similar strategies, is also identified.
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PART I

INTRODUCTION AND OUTLINE OF THE STUDY
CHAPTER 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

Capital investment decision-makers are confronted with the question of what considerations tip the balance in accepting or rejecting an investment proposal. However, the theoretical advances have been numerous and continue to come forward as refined sophisticated (i.e., discounted cash flow) capital budgeting techniques for selecting or rejecting projects. On the other hand, however, theory which concentrates in the applicability of the strategic aspects in investment decision-making is hard to find.

In a review of existing surveys on capital budgeting practices in the United States, Mukherjee and Henderson (1983:86) summarized the following four (4) limitations of DCF models for analysis of capital investments:

1. an inability to capture the role of organisational structure and behaviour in corporate decision-making: This may also include the essential societal dimension of project management (see Bamberger, 1988:5);
2. a failure to incorporate management behaviour toward risk;
3. difficulties in application due to unrealistic assumptions about data availability, this may also include amongst others certainty, risk and inflation; and
4. inability to incorporate strategic consideration in decisions made by the firm.

The above reviews confirm that DCF models give more weight to tangible and quantitative factors in capital budgeting analysis than to considering other, more intangible and qualitative factors.

1
This study will analyse and correlate the South African manufacturing sector with regard to the limitations mentioned above, namely, limitation: (1) an inability to capture the role of organisational structure and behaviour in corporate decision-making and limitation: (4) an inability to incorporate strategic considerations in decisions made by the firm.

1.2 IMPORTANCE OF THE STUDY

This study of strategic aspects in investment decision-making is important because of its role to support the management in maximizing the value of the firm for its owners. The following factors have to be considered:

1.2.1 Importance of capital budgeting in the firm and in the national economy

Usually the investment decisions of business enterprises involve large sums of money and have a significant impact on the investing firm and on the economy as a whole. South African statistics (1994: 12.65) indicate that in 1992, the total capital expenditure in South African manufacturing firms, buildings and improvements, construction works, machinery and other equipment, as well as vehicles, exceeded R12 billion compared to R4.945 billion invested in 1982, which represents an increase of more than 200% over the period.

Figure 1.1 illustrates the trends of investments in SA manufacturing firms (refer to Appendix A for figures). The investment grew from R4.945 billion to R5.385 billion in 1983. This was followed by a decrease in 1984 which continued down to R3.473 billion in 1986. Again a continuous growth in the years that followed up to 1990, amounted to R13.927 billion in 1990 which was then followed by a slight decrease to R12 billion in 1992.

Seitz (1990:13) argues that capital investment is also important to the economy because sharp increases in capital goods can lead to an overheated economy and inflation, whereas sharp decreases can lead to economic recession which can lead to a decrease of demand in the industry.

\[^{1}\] Note that we are concentrating solely on nett figures, inflation rates are not taken into consideration.
c) using a realistic method to evaluate the economic worth of the investment proposals in view of the availability, cost and alternative uses of capital.

III. Making the decision based on the foregoing evaluation of the economic worth of the investment proposals, any significant intangible factors, and managerial judgement.

IV. Post-auditing decision to improve management's forecasting, evaluation, and decision-making procedures in the future.

In general, it is during phases I and II of the capital budgeting process (which is the planning phase, namely identification of investment ideas and evaluation of proposals), that opportunities, proposals and projects are either accepted or rejected. The two first phases of the investment process are very important for investment decision-making and this study will be based on those phases.

1.2.3 A framework for linking the capital budgeting decision to the firm's long term strategy

The identification of opportunities in capital budgeting is directly linked to the enterprise's strategic goals and market position. Solomon and Pringle (1980:465) argue that "top management can best pursue maximization of owner's wealth by considering other interest groups, such as employees, customers, suppliers, creditors, government, and the public at large, all of whom have an interest in economic efficiency".

Pinches (1982:6-19) lists several approaches to strategic planning including the Boston model, which trades off market growth. He proposed a similar model, which trades off risk against return, for evaluating strategic investment decisions and maintains that:

... unless capital budgeting provides some direct relationship with and guidance for the development of the strategic objectives. The implicit assumption is that capital budgeting is only relevant given that the strategic objectives of the firm have already been determined employing (hopefully) other criteria as surrogates for long-run maximisation of the value of the firm.

In order to link capital budgeting to long term strategy, an adjunct methodology called the analytic hierarchy process (AHP) is examined for screening important factors of capital budgeting (Saaty, 1980). AHP may be considered to be superior to other techniques because:
1. it incorporates both tangibles and intangibles,
2. it improves the consistency in judgement as compared to one multi-attribute decision model, and
3. it is flexible since the hierarchical structure can be modified easily without substantially disrupting its performance.

An analytic hierarchy process requires that qualitative factors (the key success factors) relating company to project be delineated. AHP provides a consistent methodology that helps to link strategic priorities with investment decisions.

Liberatore et al (1992:32) insist that the AHP has been effective in structuring many types of complex multi-criteria business projects, especially projects with strategic considerations. For example, in the United States, AHP has recently been applied to the problem of risk assessment, subunit performance evaluation, R&D project selecting, and real estate investment. The AHP enables decision-makers to structure a problem in the form of a hierarchy of its elements and to capture managerial decision preferences through a series of pairwise comparisons of relevant factors or criteria.

However, Mukherjee (1983:53) states the following regarding the general perception of theory and practice in the actual world:

... there is a popular feeling that "theory" is opposed to "practice". This is a false conclusion based on false supposition. If practice has long been successful and does not conform to the theory, the theory is bad and in need of revision. The distinction should not be between theory and practice; it should be between good theory and bad theory, between good practice and bad practice. Practice is brick; theory is mortar. Both must be good and are essential in order to present a worthy structure.

After a review of the importance of this study, the following section outlines the research objectives formulated in order to test the efficiency or effectiveness of the capital budgeting theory against practice.
1.3 RESEARCH OBJECTIVES

The objectives of this research are:

* to determine the different capital investment processes (phases) that South African manufacturers use in the capital budgeting process and to discover whether there is due consideration of strategic aspects in their investment decision-making,
* to determine whether there is correlation between size and type of manufacturers and the use of strategic planning,
* to establish the reasons for manufacturing firms not making use of strategic aspects in their investment decision-making process.

1.4 RESEARCH METHODOLOGY

The study comprises two phases, namely a literature study and an empirical research phase. Each phase will now be briefly outlined.

1.4.1 Literature study phase

The literature study phase comprises a selection of local and international books, journals and publications on current capital budgeting theories and practices. The first chapter of the literature study deals with the capital budgeting process. This is followed by two chapters, one on the application of the theory of strategic aspects in investment decision and another one on the outline of the theory of the AHP hierarchies in order to link capital budgeting to the firm's strategy. The literature study will serve as a foundation of reference for the development of the questionnaire and the empirical study.

1.4.2 Empirical research phase

The empirical research phase will take the form of a survey aimed at the South African manufacturing sector. The survey will be in the form of a questionnaire designed to investigate the extent to which the strategic aspects selected in the literature study are being employed by South African manufacturing firms. Due to the time and cost restraints it was decided to limit the study to the South African manufacturing sector. The Gauteng region,
as may be deduced from its large contribution to the gross domestic product (refer to table 5.1), has the advantage over other regions in the country regarding number of establishments, employment figures and value of output. A further limitation to the survey is, therefore, the selection of manufacturing firms in the Gauteng region (see table 5.3).

The Standard Industrial Classification (SIC) of the Bureau of Market Research (BMR) was used to select a random sample of 361 manufacturing firms in the Gauteng region (Pretoria/Witwatersrand/Vereening) of the South African manufacturing sector. The study is aimed at a sample of private and public companies within the manufacturing sector of South Africa. The manufacturing sector has been chosen as the universe because of the important contribution of this sector to the gross domestic product of the country. In 1987 for example, the manufacturing sector contributed 23,5 percent to the gross domestic product of the country with the next largest sector contributing only 15,3 percent (South African Statistics, 1990). A mailed questionnaire, accompanied by a covering letter explaining the purpose of the study, was directed to the chief financial officer of each firm selected. The questionnaire was designed to obtain information on:

- size and activity-type of the manufacturers
- investment selection process of the firm
- impact of strategic aspects in decision-making
- awareness of AHP
- reasons for not using AHP methodology.

The data gathered from the survey will be used to draw conclusions on the practice of the analytic hierarchy process theory by South African manufacturers. Correlations between size and type of manufacturer and use of this methodology will be drawn. Popular use of any investment method will be highlighted as well as common reasons for not using AHP. Conclusions drawn and further recommendations regarding future research in this area will form the final chapter of this study.

1.5 SCOPE OF THE STUDY

The study comprises three parts. Part One introduces the topic and states the objectives of the report as well as the background for the empirical study.
Part Two deals with the literature study on which the empirical research will be focused. It consists of two chapters, Chapter Two covering the capital budgeting process and Chapter Three deals with the theory and methodology of strategic aspects relating to investment decision-making. Chapter Four discusses the method undertaken to link capital budgeting to the firm's strategy.

Part Three deals with the empirical study and consists of three chapters. Chapter Five sets out the methodology of the empirical study, Chapter Six contains the analysis of the results obtained in the survey and Chapter Seven presents a summary, conclusions drawn and recommendations.
PART II

LITERATURE STUDY
CHAPTER 2

THE CAPITAL INVESTMENT PROCESS

2.1 INTRODUCTION

The purpose of this chapter is to discuss the capital investment process. The capital investment process can be defined as the efficient allocation of capital to investment proposals, the benefits of which are to be gained at some stage in the future. This allocation of capital among alternatives must be made in accordance with the underlying objective of the firm, which is to maximise the value of the firm for its owners (Brigham and Gapenski, 1990:5).

The different phases of capital investment will be discussed. Some factors affecting those phases, such as management action and attention toward the decision rules, will be considered. Finally a comparison between theory and practice of capital budgeting will be established.

2.2 IMPORTANCE OF THE CAPITAL INVESTMENT PROCESS

The importance of the capital investment process lies in management's responsibility to the owners of the company for effective allocation of their funds. There are two reasons for this:
the owners have the right to expect a fair rate of return on their invested capital
even though the owners' wealth maximizing is the prime objective of the firm,
management must also look at other non-financial objectives such as customer
and employee satisfaction which affect indirectly the firm's value.

2.3 THE CAPITAL INVESTMENT PROCESS

The theory on the capital investment process is generally well known and continue to expand on the selecting or rejecting of projects. Pinches (1982:9), for instance, applied a four-stage model to capital budgeting. These stages are:

1. identification of an investment opportunity,
2. development of an initial idea into a specific proposal or project evaluation,
3. implementation of a project,
4. control, including post-audit, to assess forecast accuracy.

Each stage has aspects of interest. In the case of identification, for example, it would be helpful to know where the proposals come from, the process by which they are forwarded for consideration and nature of the screening process. All four stages will be discussed in later sections.

Whereas the capital budgeting process is not without its critics, Pinches (1982:16) emphasises that both the theory of the capital budgeting process and its practice can be viewed as myopic, by stating:

The main failure of academicians is due to focusing too much of their attention on the selection phase to the exclusion of the identification, development, and control phases. Very little attention has been given to the interface between strategic planning and capital budgeting. ... Business executives, on the other hand, have been equally myopic concerning the capital budgeting process. While many of them are very aware of the different phases, the interrelationships between phases are often not dealt with effectively.
Mukherjee and Henderson (1987:88) believe that the capital budgeting process entails more than calculating the cost of capital and nett present values.

Brigham and Gapenski (1990:5) assume that management's primary goal is to maximize the firm's value. Capital budgeting theory prescribes decision rules in keeping with these objectives. But to what extent are those rules satisfied or affect the attention of management regarding decision-making? To answer this question, we first reviewed the four-stage framework of the capital investment process, which is illustrated in Figure 2.1, and which shows clearly how the four phases of the capital investment process, namely identification and generation of investment ideas; project evaluation which include three steps; project implementation; and post implementation audit and control, are related between them.

**Figure 2.1: Example of the Capital Budgeting Process**

![Diagram of the Capital Budgeting Process](source: Adapted from Halloran & Lasco (1985:37C))
2.3.1 Identification and generation of investment ideas

Identification and generation of investment ideas is the first phase of the investment process to be taken into consideration. This phase establishes the goals and objectives of the business. In other words, identification and generation of investment ideas defines clearly the reason for being in business. It is directly linked to the enterprise's strategic goals and market position.

Identification and generation of investment ideas is the crucial phase of the investment process. It is during this phase that strategic aspects of investment must be taken into consideration.

In his survey, Istvan (1961:4-8) found that only one of the 48 firms he interviewed made any special effort to stimulate capital investment ideas. On the other hand, the findings of Klammer (1972:387-397), are at odds with those of Istvan: 82 percent of Klammer's firms had investment search procedures in 1959, and by 1970, this had grown to 94 percent.

In today's world, business is exposed to fast growing technology which requires that management pays attention to its environment. The changing environment has caused many companies which previously did not take serious consideration of strategic aspects to rethink their objectives.

By trying to maximize the firm's value, the management runs a risk of limiting its attention to the quantifiable factors by neglecting numerous key (strategic) factors, such as competitive forces and organizational structure, that need to be taken into consideration by management in order to attain the objective of wealth maximization, and wealth maximisation may be seen as a rather abstract concept. Identification of investment ideas must be given more weight when making investment decisions.

The following section outlines the business objectives of identification and generation of investment ideas, namely financial and non-financial objectives.
2.3.1.1 Financial objectives

The financial objectives of the company's capital expenditure policy are to provide adequate funds to maintain facilities for the present lines of business and to seek out opportunities for the investment of funds which may improve sales, reduce costs, and, therefore, improve earnings. Ideally, these are the attainable goals that managers believe will increase shareholder wealth the most (Istvan, 1961:3).

2.3.1.2 Non-financial objectives

Financial objectives are not always the sole determinants of capital budgeting in order to attain wealth maximization. Studies (conducted by Solomon and Pringle, 1980; Porter, 1980; Pinches, 1982; Saaty, 1980) have shown that other non-financial objectives need to be taken into account when analysing proposals. Those non-financial objectives include environment enhancement, personnel welfare and safety, assurance of supply of essential products, competitive forces, product quality, and compliance with laws and government controls.

2.3.2 Project evaluation

Project evaluation is the second phase of investment process. It is the aspect of capital budgeting that has received the most attention from management; indeed, every capital budgeting source consulted in the course of this research referred to this phase.

Firms usually classify projects by types and allow some classifications to be exempted from financial justification. Rosenblatt (1980:259-273) found that firms typically classified projects and used acceptance and selection criteria that are dependent upon the classification. Klammer and Walker (1984:137-148) reported that required documentation can vary with classification; for instance, standard forms are waived for urgent projects. Weaker proposals are apparently eliminated by pre-screening during evaluation phase.
The following sections outline the project evaluation steps:

2.3.2.1 Search for investment opportunities

The first part of project evaluation is the development of realistic goals and sound strategy. Then specific attention must be devoted to the search process.

A successful search generally requires financial commitment of resources. Research, product development, and consumer attitude research are used to identify investment opportunities. Training of the staff in support of the firm's strategy is another example of facilitating a successful search. Chief executives are increasingly aware that training of employees is not a sideline activity, but an important part of strategy implementation.

A wealth maximizing capital budgeting system must also be part of a corporate culture that encourages people to consider new possibilities.

2.3.2.2 Selection of investment alternatives

Investment opportunities will denote projects and proposals available for investment. Distinct combinations of investment opportunities will be used to define the investment alternatives which lead to the selection stage.

Many firms have adopted sophisticated techniques, called discounted cash flow (DCF), in order to select investment alternatives. This has been demonstrated by the following series of studies (Oblak and Helm, 1980:37-41; Kim and Farragher, 1981:26-30; Klammer and Walker, 1984:137-148), and the DCF analysis is becoming a standard practice. The internal rate of return is the favoured DCF technique with nett present value being a distant second choice (Klammer and Walker, 1984). Afflect et al (1986:7-9) in their surveys of investment analysis conducted in South Africa, state that the investment appraisal method is used less often in South Africa than in the United States of America and the technical analysis is perceived as being more useful for investment analysis in South Africa.
In their summary, Afflect et al (1986:7-9) state that

... Most firms use non-discounted cash flow techniques as a secondary form of analysis. The most frequently used are payback period and accounting rate of return.

According to the surveys cited above, among many other methods illustrated by financial text books, there are five principal capital budgeting techniques used by the business sector. These five capital budgeting techniques which will be discussed are:

* Payback period
* Accounting rate of return (ARR)
* Nett present value (NPV)
* Internal rate of return (IRR)
* Profitability index (PI).

2.3.2.2.1 Payback period

The payback period is the exact amount of time required for the firm to recover the initial investment (cash outlay). It is simply the ratio obtained by dividing the original fixed investment in an asset by the nett annual incremental cash flow expected.

The payback period is a quick and simple method to calculate and provides a rule where projects are only accepted if the initial cash outflow is recouped within a predetermined time.

Whilst the time value of money may or may not be elaborate, the payback period may be used to address in investment risk.

2.3.2.2.2 Accounting rate of return (ARR)

The accounting rate of return (ARR), which looks at a project’s contribution to nett income rather than its cash flow, is the second oldest evaluation technique. In its most
common form, the ARR is measured as the ratio of the project's average annual expected nett income to its average investment (Brigham and Gapenski, 1990:265-266).

2.3.2.2.3 Nett present value (NPV)

The nett present value gives explicit consideration to the time value of money, it is considered to be a sophisticated capital budgeting technique. Gitman (1991:385) states that:

... all such [capital budgeting] techniques in one way or another discount the firm's cash flows at a specified rate. This rate - often called the discount rate, opportunity cost, or cost of capital refers to the minimum return that must be earned on a project in order to leave the firm's market value unchanged.

NPV is found by subtracting the initial investment (II) from the present value of the future nett cash inflow (CF), discounted at a rate equal to the firm's cost of capital (k) (Gitman, 1991:384).

The NPV is formulated as follows: Equation 2.1

\[
NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+k)^t} - II
\]

Where:  
\( CF \) = Cash inflow  
\( II \) = initial investment  
\( k \) = the project's cost of capital

It should be noted that cash outflows such as initial investment are treated as negative cash flows.

Brigham and Gapenski (1990:267) outline the following decision criterion: if the NPV is
positive, the project should be accepted, if the NPV is negative, it should be rejected; and if two projects are mutually exclusive, the one with the highest NPV should be chosen.

2.3.2.2.4 Internal rate of return (IRR)

The most useful method of calculation of the internal rate of return for a single project involves finding the interest rate at which the present value of the nett cash inflows equals the present value of the cash outflows. In other words, the IRR is the discount rate that equates the NPV of an investment opportunity with zero (since the present value of cash flows equals the initial investment).

Mathematically, IRR is found by solving equation 2.1 for the value of r that causes NPV to equal zero. Equation 2.2 can be formulated as follows:

$$\text{IRR} = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} - II = 0$$

Where:  
$CF_t$ = the expected cash inflows in period $t$  
$II$ = the initial investment  
$r$ = the internal rate of return

For IRR, Brigham and Gapenski (1990:269) advocate the following decision criterion: if the IRR is greater than the cost of capital, accept the project; if the IRR is less than the cost of capital, reject the project. This criterion guarantees that the firm earns at least its required return.

When conflicts exist between NPV and IRR methods for decision-making in a set of mutually exclusive projects, the NPV method is superior to the IRR method because it
gives a direct measure of the rand benefit (on a present value basis) of a project.

Under conditions of capital rationing and mutually exclusive proposals, care has to be taken when applying the IRR technique. In addition, unconventional cash inflow may give rise to the incorrect decision.

The following is an illustration of the NPV and IRR method, using an example from Brigham and Gapenski (1990:263).

<table>
<thead>
<tr>
<th>Year (t)</th>
<th>Project A</th>
<th>Project B</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>(1 000)</td>
<td>(1 000)</td>
</tr>
<tr>
<td>1</td>
<td>450</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>300</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>550</td>
</tr>
</tbody>
</table>

At a 10 percent cost of capital, the NPV formula (equation 2.1) is applied in order to evaluate projects A and B. The nett present value of Project A is R43.55, while the nett present value for Project B is -R9.56. According to the decision criterion that Brigham and Gapenski (1990:267) outlined, Project A should be accepted because it has a higher NPV value and Project B should be rejected.

The IRR formula or equation 2.2, is not easy to calculate by hand. At a 10 percent cost of capital and with the assistance of a financial calculator, the internal rate of return (IRR) for Project A is 12.14%, while the IRR for Project B is 9.70%. In this case Project A should be accepted because it is expected to earn more than the cost of the capital needed for financing (Brigham and Gapenski, 1990:269).

2.3.2.2.5 Profitability index (PI)

The profitability index, also known as the benefit-cost ratio, is computed by dividing the
present value of nett cash inflows by the present value of cash outflows (Brigham and Gapenski, 1990:270).

The profitability index (PI) uses the same discount rate as is used in the nett present value (NPV) system.

In equation 2.3:

\[
P_l = \frac{\sum_{t=1}^{n} \frac{CIF_t}{(1+k)^t}}{\sum_{t=0}^{n} \frac{COF_t}{(1+k)^t}}
\]

Where:  
- \( CIF_t \) = the expected cash inflows or benefits in period \( t \)  
- \( COF_t \) = the expected cash outflows or costs in period \( t \)  
- \( k \) = the project's cost of capital

If a PI is less than one, this means that the present value benefits of the project are less than the initial capital outlay, and the project should be rejected. If the PI is greater than one, the project should be accepted. NPV and PI will always give the same accept/reject decisions; the only difference is that PI is a ratio while NPV shows the rand value of benefits.

2.3.2.3 Evaluation of the decision rules

We have presented five principal capital budgeting rules, all of which are used to a greater or lesser extent in practice. However, those methods can sometimes lead to the different accept/reject decisions, so we need to answer the question: which method is the best, where "best" is defined as the method that selects the set of projects that maximizes the firm's value and, hence, shareholder wealth. Brigham and Gapenski (1990:271) argue that if more than one method does this, then the best method would
Brigham and Gapenski (1990:271) further present three properties that must be exhibited by a selection method if it is to lead to consistently correct capital budgeting decisions:

1. The method must consider all cash flows throughout the entire life of a project.
2. The method must consider the time value of money; that is, it must reflect the fact that the rand which comes in sooner is more valuable than the rand which is received in the distant future.
3. When the method is used to select from a set of mutually exclusive projects, it must choose that project which maximizes the firm's value.

Now, how do the five methods discussed above stand in regard to the required properties? This question may be answered as follows: both the regular accounting rate of return and the payback period violate property 1, because they usually do not consider cash flows at all. Additionally, the undiscounted payback and accounting rate of return also violate property 2. The accounting rate of return uses accounting income rather than cash flow and it does not differentiate between earlier and later rand value. The NPV, IRR, and PI methods all satisfy property 1 and 2, and all three may lead to identical and correct accept/reject decisions for independent projects.

However, only the NPV method always satisfies property 3, because there are certain conditions under which the IRR and the PI methods fail to correctly identify the project (especially in a set of mutually exclusive projects) which maximizes the firm's value.

Thus, the NPV method seems to be the best capital budgeting technique in order to maximize the firm's value.

2.3.2.4 Investment decision hierarchy

The selection of investment is typically a multi-level process, usually involving plant managers, division vice president and a capital budgeting committee. The process is also related to the importance of the amount and the size of the projects. Decisions on
very large investments are typically made by a capital budgeting committee or the chief executive.

Viewed in a broader context, though, capital budgeting begins with encouraging people to search for investment opportunities and culminates with the selection of the investments that make the greatest contribution to company goals. Therefore, the information gained from evaluation of a number of investment proposals feeds back into strategic planning.

2.3.3 Implementation of the project

Gitman and Mercurio (1982:21-29) provided the best and most specific information on project approval.

Once a project has been chosen or approved, the implementation and monitoring processes begins. Capital investments are monitored during the actual period of acquisition or construction and deviations must be identified in order to take corrective actions. In this area, the more modern techniques of project management are applied.

2.3.4 Post-implementation audit and control

The post-audit is primarily a learning tool because it is carried out at the end of a capital investment's life or after the investment has matured to a stable level of activity and profitability. The post-audit includes an assessment of the actual performance of the investment and a comparison with the forecasted performance. Reasons for deviation from anticipated performance are sought. Post-audits allow firms to identify the strengths and weaknesses of their capital-budgeting system and to take corrective actions and/or to revise the capital budgeting system.
2.4 DEFICIENCIES OF THE RELEVANT THEORY OF CAPITAL BUDGETING AS COMPARED TO PRACTICE

Mukherjee and Henderson (1987:85) state that:

... contrasting capital budgeting practices with theory reveals a number of deficiencies. This is most apparent in the selection, which has been a primary focus of financial theory and is the most closely examined aspect of business practice...

The above statement relating to the literature of the capital budgeting process leads one to believe that the differences between theory and practice can be attributed to deficiencies in the theory itself.

In their summary, Mukherjee and Henderson (1987:88) said that "business has learned from academia. Now it appears time has come for academia to learn from business".

Existing theory assumes that capital budgeting decisions are based solely in economic analysis. However, in an organizational environment, other factors such as politics, intuitions, business structure and lack of effective communication may also play an important role.

By comparing the shortcomings of the capital budgeting theory, it appears that the DCF techniques fail to consider the strategic environment in which corporate decisions are made. Considering the capital budgeting process as part of overall company operations requires that the models consider a firm's strategic needs to grow and innovate.

In keeping with these needs, the firm makes many investment decisions today to create investment opportunities for tomorrow.

Such investment decisions include investments in research and development with a negative NPV project today in order to establish a foothold in a market with strong growth potential in the future.
Concerning the limitations of the DCF approach for taking into consideration strategic aspects in investment decision-making which involve "time series links between projects", Myers (1984:126-137) suggests applying option pricing theory instead. Pinches (1982:6-19) even went so far as to characterize this topic as "myopic".

2.5 CHAPTER SUMMARY

This chapter has dealt with the four phases of capital investment: Identification and generation of ideas, project evaluation, project implementation, and post-implementation audit and control. Shareholder wealth maximization is viewed as the primary objective of financial management. It appears that managers give more weight to the sophisticated capital budgeting techniques, which are NPV, IRR, and PI, in evaluating the capital investment. They may often ignore other tangible factors.

The study indicates several inconsistencies between theory and practice. Such inconsistencies (gaps) are most evident at the selection stage because of the difference between theory and business practice.

Although, this chapter has presented the basic elements of the capital investment process which are well known in practice, there are other aspects of this crucial topic especially strategic aspects, which need to be dealt with in more detail when making investment decisions. The following chapter will focus on the planning phase of investment and the strategic aspects will be addressed as well.
CHAPTER 3

STRATEGIC ASPECTS IN INVESTMENT

3.1 INTRODUCTION

The previous chapter dealt with different steps of the investment process, and several inconsistencies between the pertinent theory and practice of capital budgeting. Amongst others, was the drawing of management attention to the use of discounted cash flow (DCF) instead of taking into consideration other investment strategic factors. This chapter will focus on the two first steps of the capital budgeting process namely, identification and generation of investment ideas and strategic evaluation of projects, which may also be referred to as the planning phase of the investment process.

Clarke et al (1988:1) state that:

Strategy should provide a picture of what the organization wants to be in the future: strategy is vision. It is directed at what the organization should be rather than how it will get there.

Strategic aspects in investment consist of setting ways to help management in decision-making regarding selection of projects. The importance of strategic aspects is to select from among others, an investment that maximises the value of the firm to its owner(s), by taking into consideration quantifiable, as well as non-quantifiable factors, in investment decision-making.
The objective of this chapter is to develop the key success factors which affect short- and long-run investment decision-making in order to offer guidance to the management to facilitate consideration of the strategic concepts.

### 3.2 ROLE OF STRATEGIC ASPECTS IN INVESTMENT

Strategic aspects help to provide a formal statement (criteria) to the firm's management in order to search for, and evaluate investment opportunities. Conversely, strategic planning guides the search for projects by identifying promising product lines or geographic areas in which to search for good investment opportunities.

Due to the important role of strategic planning in investment decision-making, all of the following authors (Bromwich, 1991:66-71; Govindarajan, 1989:251-269; and Mensah, 1989) believe a new decision approach may be needed in order to:

1. identify relevant attributes (both qualitative as well as quantitative) representing important benefits of capital investment;
2. relate the importance of these attributes to achieving the firm's strategy; and
3. formalize the decision process with a systematic approach that links the firm's strategy to the ultimate decision.

While financial procedures for choosing an existing set of alternative projects are well established as described in Chapter Two, there is still little, if any, discussion as to how top management should evaluate the appropriateness of the whole batch of proposed projects, from the viewpoint of corporate objectives. And yet this latter evaluation, rather than the individual assessment of specific investment projects, is the key to the attainment of corporate purpose. This is true for two reasons:

a. The most important strategic alternative might not be included in the existing set of suggestions, and under the procedures used for generating proposals in most companies, they are not likely to be.
A critical characteristic of the set of investment alternatives chosen, is its attributes as a set, rather than the level of return of the project individually. For instance, each of a set of projects may offer a good return, but as a whole, the set may impose excessive strain on corporate money resources, or fail to take into account critical competitive development.

Porter (1980:3-33), who is known as an authority on competitive strategy, contends that a corporation is most concerned with the intensity of competition within its industry.

The level of this intensity is determined by basic competitive forces. The collective strength of these forces determines the ultimate profit potential in the industry, where profit potential is measured in terms of long run return on invested capital.

3.3 COMPETITIVE FORCES

3.3.1 Introduction

The essence of formulating competitive strategy lies in relating a company to its environment. Forces outside the industry are significant primarily in a relative sense: since outside forces usually affect all firms in the industry, the key is found in differing abilities to deal with those forces (Wheelen and Hunger, 1992:98).

According to Porter (1980:3-33), the state of competition in an industry depends on five basic competitive forces namely:

1. Potential entrants — threat of new entrants.
2. Suppliers — bargaining power of suppliers.
4. Substitutes — threat of substitute products or services.
5. Industry competitors.
Freeman (1984:140-142) recommends adding a sixth force to Porter's list: this is the "relative power of other shareholders".

Porter (1985:4) further states that:

Knowledge of the underlying sources of pressure highlights the critical strengths and weaknesses of the company, animates its positioning in its industry, clarifies areas were strategic changes may yield the greatest payoff and highlights the areas where industry trends promise to hold the greatest significance as either opportunities or threats.

Wheelen and Hunger (1992:99-106) say that "... in carefully scanning its industry, the corporation must assess the importance to its success of each of the six competitive forces".

Therefore, all six competitive forces (five listed by Porter, and one added by Freeman) will be discussed as follows:

3.3.2 Threat of new entry

New entries to an industry typically bring to it new capacity, a desire to gain market share and substantial resources. They are, therefore, threats to an established corporation. The threat of the entry depends on the presence of entry barriers and reaction that can be expected from existing competitors.

Wheelen and Hunger (1992:100-101) listed seven majors sources of barriers to entry namely:

1) Economies of scale,
2) Product differentiation,
3) Capital requirements,
4) Switching costs,
5) Access to distribution channels,
6) Cost disadvantages independent of size, and
7) Government policy.
Each will be discussed in more detail later in this chapter.

### 3.3.2.1 Economies of scale

Economies of scale refer to the cost advantages associated with size. Scale economies deter new entrants by forcing the entrant to enter the industry at a large scale (usually with high costs) and so risk reaction from existing firms, or to enter the industry at a small scale and accept a cost disadvantage.

### 3.3.2.2 Product differentiation

Product differentiation requires a brand identification which creates a barrier to entry by forcing entrants to spend heavily to overcome existing customer loyalty. Advertising, customer service and being first with a new product foster brand identification.

### 3.3.2.3 Capital requirements

The firm needs to invest large financial resources in order to compete. This creates a significant barrier to entry, particularly if it is for unrecoverable up-front expenses such as R&D.

### 3.3.2.4 Switching costs

Switching costs are the one-time costs facing a buyer when that buyer switches from one supplier’s product to another’s. If the switching costs are high, a new entrant must offer a major improvement in cost or performance to entice a potential customer to change from its regular supplier.

### 3.3.2.5 Access to distribution channels

A barrier to entry can be the new entrant’s need to secure distribution for its products. To the extent that appropriate distribution channels have already been used by established firms,
the new entrant must persuade the channels to accept its products through costly promotion allowances.

3.3.2.6 Cost disadvantages independent of size

An established company may have costs advantages not easily imitated by new entrants. These may be proprietary product knowledge protected by patents, favourable access to raw materials, favourable locations, or government subsidies.

3.3.2.7 Government policy

The government can limit entry into industry through licensing requirements and limits on access to needed raw materials.

3.3.3 The intensity of rivalry among existing competitors

Rivalry among existing firms takes the familiar form of jockeying for position. In most industries, competitors are mutually dependent. A competitive move by one firm can be expected to have a noticeable effect on its competitors and thus may cause retaliation or counter effort.

Intense rivalry is the result of a number of interactional structural factors as described below:

3.3.3.1 Competitors

Competitors are either numerous or roughly of equal size and power. When competitors are numerous, there is plenty of room for new strategies to be tried by one firm and copied by others. When competitors are roughly equal in size, they watch each other carefully to make sure that any move by another firm is matched by an equal countermove.
3.3.3.2 **Industry growth**

When industry growth is slow, it generates fights for market share by expansion-oriented companies. When an industry is growing rapidly, there is usually plenty of opportunity for many firms to grow within it. When industry grows slowly, however, it becomes much more difficult for any one firm to continue sales growth unless it takes sales away from competitors.

3.3.3.3 **The product or service**

The product or service is undifferentiated or lacks switching costs. When a product or service is basically the same regardless of the company offering it, that product or service basically becomes a commodity.

3.3.3.4 **Fixed costs**

Fixed costs are high or the product is perishable. To the extent that a company's fixed costs are high, it may be willing to cut prices below its total costs in order to cover at least its fixed costs.

3.3.3.5 **Capacity**

Capacity is normally added in large increments. If the only way a company can increase its manufacturing capacity is to add it in a large increment by building a new plant, it will run that new plant at full capacity to keep its units costs as low as possible. This is especially likely if there are economies of scale present in the production of that product.

3.3.3.6 **Exit barriers**

Exit barriers are high. The reverse of entry barriers, exit barriers keep a company from leaving an industry. These barriers may be specialized assets or management's loyalty to an existing business. To the extent that a firm finds it very difficult to exit an industry, it will continue to compete as long as it can and avoid losing significant amounts of money, while
management hopes that better times are on the way.

3.3.7 Rivals

Rivals are often diverse in their strategies used, origins and corporate cultures. Since diverse rivals have very different ideas of how to compete, they are likely to cross paths often and unknowingly challenge each other's position.

3.3.4 Threat of substitute products or services

Pressures from substitute products or services are high within the industry. In effect, all corporations within one industry are competing with firms in other industries that produce substitute products. Substitute products are those products that appear to be different, but can satisfy the same need as another product.

Substitute products limit the potential returns of an industry by placing a ceiling on the firm's price policy and can change the firm's profitability.

3.3.5 Bargaining power of buyers

Buyers compete with the industry by forcing down prices, bargaining for higher quality or more services, and playing competitors off against each other, all at the expense of industry profitability. Various circumstances make a buyer powerful, among others are when:

* It purchases a large proportion of seller's product or service.
* It has the potential to integrate backwards by producing the product itself.
* Alternative suppliers are plentiful because the product is standard or undifferentiated.
* Changing suppliers costs very little.
* The purchased product represents a high percentage of the buyer's costs, thus providing an incentive to shop around for a lower price.
* It earns low profits and is thus very sensitive to costs and service differences.
* The purchased product is unimportant to the final quality or price of the buyer's
products or services and thus can be easily substituted without affecting the final product adversely.

3.3.6 Bargaining power of suppliers

Suppliers can affect an industry through their ability to raise prices or reduce the quality of purchased goods and services.

A supplier group is powerful if some of the following apply:

* The supplier industry is dominated by a few companies, but sells to many.
* Its product or service is unique and/or it has build up switching costs.
* Substitutes are not readily available.
* Suppliers are able to integrate forward and compete directly with their present customers.
* A purchasing industry buys a small portion of the supplier's goods and services and is thus unimportant to the supplier.

3.3.7 Relative power of other shareholders

Relative power of other a shareholder is the sixth force that Freeman (1984:140-142) recommends adding to Porter's list. This may include a variety of shareholder groups from the task environment. Some of these groups are governments, unions, local communities, creditors (if not included with suppliers), trade associations, special-interest groups, and shareholders. The importance of these shareholders will vary according to the industry.

Although Porter contends that the government influences the level of competitive activity through its previously mentioned five forces, it is suggested here that government deserves a special mention because of this strong relative power in all industries.

After addressing the impact of competitive forces in the industry, it is important to describe strategic types.
3.4 TYPE OF BUSINESS STRATEGY

In analysing the level of competitive intensity within a particular industry or strategic group, it is useful to characterize the various competitors for predictive purposes.

According to Miles and Snow (1978), competing firms within a single industry can be categorized on the basis of their general strategic orientation into one of four basic types namely:

a) Defenders,

b) Prospectors,

c) Analysers, and

d) Reactors.

Each of these types has its own combination of structure, culture, and processes consistent with that strategy. This distinction helps explain why companies facing similar situations behave differently and why they continue to do so over a long period of time. These general types have the following characteristics:

3.4.1 Defenders

Defenders are companies with a limited product line that focus on improving the efficiency of their existing operations. This cost orientation makes them unlikely to innovate in new areas.

3.4.2 Prospectors

Prospectors are companies with fairly broad product lines that focus on product innovation and market opportunities. This sales orientation makes them somehow inefficient. They tend to emphasize creativity over efficiency.

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3.4.3 Analysers

Analysers are corporations that operate in at least two different product market areas, one stable and one variable. In the stable areas, efficiency is emphasized. In the variable areas, innovation is emphasized.

3.4.4 Reactors

Reactors are corporations that lack a consistent strategy-structure-culture relationship. Their (often ineffective) responses to environmental pressures tend to be piecemeal strategic changes.

Dividing the competition into these four categories enables the strategic manager not only to monitor the effectiveness of certain strategic orientations, but also to develop the basic generic strategies which will be discussed next.

3.5 THE THREE GENERIC STRATEGIES

Porter (1980:34-46) lists three internally consistent generic strategies (which can be used singly or in combination) for creating a defensible position in the long run and outperforming competitors in an industry. Those generic strategies are:

a) Overall cost leadership
b) Differentiation
c) Focus.

Each of these factors will be outlined individually.
3.5.1 Overall cost leadership

Cost leadership requires aggressive construction of efficient-scale facilities, vigorous pursuit of cost reductions from experience, tight cost and overhead control, and so on. A great deal of managerial attention to cost control is necessary to achieve these aims. Low cost relative to competitors becomes the theme running through the entire strategy, quality, service and other areas cannot be ignored.

Having a low-cost yield, the firm shows above average returns in its industry despite the presence of strong competitive forces. Its cost position gives the firm a defence against rivalry from competitors, because its lower costs mean that it can still earn returns after its competitors have competed away their profits through rivalry.

A low-cost position defends the firm against powerful buyers because buyers can exert power only to drive down prices to the level of the next most efficient competitor.

Low-cost provides a defence against powerful suppliers by providing more flexibility to cope with cost increases. The factors that lead to a low-cost position usually also provides substantial entry barriers in terms of scale economies or cost advantages.

Therefore, a low-cost position usually places the firm in a favourable position vis-a-vis to its competitors in the industry.

Thus, a low-cost position protects the firm against all six competitive forces because bargaining can only continue to erode profits until those of the next most efficient competitors will suffer first in the face of increased competitive pressures.

3.5.2 Differentiation

The second strategy is one of differentiating the product or service offering of the firm, creating something that is perceived industry-wide as being unique or within a specific geographic area. It should be stressed that the differentiation strategy does not allow the firm
to ignore costs, but rather they are not the primary strategic target.

Differentiation, if achieved, is a viable strategy for earning above average returns in an industry because it creates a defendable position with the six competitive forces, even if it leads in a manner different to that of cost leadership. Differentiation provides insulation against competitive rivalry because of brand loyalty by customers and the resulting lower sensitivity to price.

It also increases margins, which avoids the need for a low-cost position. The resulting customer loyalty and the need for a competitor to overcome uniqueness, provide entry barriers. Differentiation yields higher margins with which to deal with supplier power, and it clearly mitigates buyer power, since buyers compare alternatives and are thereby less price sensitive.

Finally, the firm that has differentiated itself to achieve customer loyalty should be better positioned vis-a-vis substitutes than its competitors.

### 3.5.3 Focus

The final generic strategy is to focus on a particular buyer group, segment of the product line, or geographic market. The entire focus strategy is built around serving a particular target very well.

The strategy rests on the premise that the firm is thus able to serve its narrow strategic target more effectively or efficiently than competitors who are competing more broadly. As a result, the firms achieve either differentiation from satisfying the needs of the particular target, or from lower costs in serving this target, or both. Even though focus strategy does not achieve low cost or differentiation from the perspective of the market as a whole, it does achieve one or both of these positions vis-a-vis its narrow market target.
3.6 CHAPTER SUMMARY

This chapter covered the strategic aspects which should be considered in investment decision-making. It also outlined the impact of the external environment in business, which is of importance to those concerned in strategic decision-making in a corporation. The six forces driving industry competition have been discussed, followed by the type of strategy and the three generic strategies that the firm might follow in order to maximise the key success factor of investment and to cope with its competitors.

Looking at the capital investment theory and general strategy, we may identify a problem — that is, to find a way to bring these together. The next chapter will endeavour to link the capital budgeting and the firm's strategy.
CHAPTER 4

METHOD FOR LINKING CAPITAL BUDGETING TO THE FIRM'S STRATEGY

4.1 INTRODUCTION

The purpose of this chapter is to outline possible methods which may be used by management in order to create a formal link between capital budgeting and a firm's strategy.

One method which may be applied is the Analytic Hierarchy Process (AHP), in which Liberatore et al (1992:31-38) consider AHP as a framework to help guide or structure the decision process and to ensure a formal linkage between capital budgeting decisions and strategy. In their summary, Liberatore et al (1992:41) state that the use of the AHP method can formally link capital investment decisions to strategy and can alleviate some of the difficulties of attempting to capture all project benefits in the form of cash flow estimates.

The specific objective of this chapter is to explain the AHP.

4.2 THE ANALYTIC HIERARCHY PROCESS (AHP)

4.2.1 Introduction

The analytic hierarchy process is a theory developed by Thomas L. Saaty in 1971 (see
Saaty, 1990:ix-xii). The AHP method was applied in 1973 in order to resolve the Sudan Transport problem. More recently the method has been applied to various problems, amongst which are the problems of risk assessment, subunit performance evaluation, R&D project selection, real estate investment, and so on.

The analytic hierarchy process consists of a theory of measurement and it is considered to be a decision-making tool. It assists the decision-maker to describe the general decision operation by decomposing a complex problem into a multi-level hierarchic structure of objectives, criteria, subcriteria and alternatives. Saaty and Kearns (1985:19) define the analytic hierarchy process as:

a systematic procedure for representing the elements of any problem, hierarchically. It organises the basis rationally by breaking down a problem into its smaller and smaller constituent parts and then guides decision makers through a series of pairwise comparison judgments (which are documented and can be re-examined) to express the relative strength or intensity of impact of the elements on the hierarchy.

It should be noted that this chapter will focus only on the basic theory for formulating the AHP hierarchy. For further development refer to Saaty (1986:841-855) which is in Annexure A, and Saaty (1990:1-36). The next section lists different steps in applying the analytic hierarchy process.

4.2.2 Steps in applying the AHP

It would appear that the AHP is relatively easy to use. After underlining all its important elements such as the ratio scales based on criteria set, followed by a relative comparison considered as a measurement tool which leads to the ranking decision alternatives. The AHP allows a psychometric scale (relative measurement) to quantify managerial judgements, and provides a method to measure the consistency of those judgements. The key is that capital projects funded are consistent with the overall strategy of the firm.

Liberatore et al (1992: 32) listed the following five essential steps in order to apply the AHP in practice:
1. Structuring the decision hierarchy
2. Collecting data by pairwise (relative) comparisons
3. Checking consistency of managerial judgment
4. Applying the eigenvector (a proper or characteristic vector obtained after multiplying a matrix by a vector) method to compute weights; and
5. Aggregating the weights to determine a ranking decision alternatives.

The value achieved from a AHP analysis is highly dependent on interrelationships defined across the various levels of the firm's hierarchy. Yet, as emphasized earlier, there has been little discussion in the literature involving the development of appropriate corporate objectives to guide the capital budgeting process, especially step 1 above. Though appropriate hierarchy design is critical to the process of linking the firm's capital budgeting to strategy and investment decisions, this dissertation focuses on the initial step of the AHP process. The following section describes briefly different approaches in order to develop that initial step.

4.2.3 Approaches for developing AHP hierarchy for capital budgeting

In order to be explicit in this topic, it is necessary to clarify the kinds of decision problems that managers may face in the justification of new manufacturing technology:

Firstly, assume that business strategies do not need to be stated explicitly in order to develop an appropriate set of evaluation criteria.
Secondly, incorporate economic value in the hierarchy process.
Thirdly, utilise a specific planning theme or methodology in the construction of the hierarchy; or
Fourthly, develop a hierarchy based on the mission, objectives, and strategies (MOS) approach to planning.

We will refer to these kinds of decision problems as formal, economic value, value chain, and planning hierarchy problems.
The organisation could be made operational through a generic three-level hierarchy with the following components:

1) GOAL of the hierarchy, which is to select the best capital projects for investment;
2) CRITERIA for evaluating capital projects, and
3) ALTERNATIVES, that is, the capital projects themselves.

Since we are assuming that management fully understands the strategy of the firm, an appropriate set of evaluation criteria can be readily identified. Because of the subjective nature of some projects' benefits, evaluation criteria should be developed by a team representing the three primary functions of the business, namely finance, marketing, manufacturing functions.

A major benefit of a team approach is that the differing impacts and viewpoints are synthesised into a set of criteria acceptable to all (Liberatore et al, 1992:32).

However, the basic approach of AHP constructs different hierarchies for benefits and costs. The benefits hierarchy structure links the decision criteria to a strategic or operational category. The category weight is used to adjust the overall weight of each benefit criterion. On completion of projects with respect to all the benefit and cost criteria, an overall benefit weight and a cost weight is determined for each project. Benefit-cost ratios are formed to facilitate the final selection of alternatives.

The primary advantage of the basic AHP approach is its simplicity: once the criteria are agreed upon and supporting data collected for each project, the AHP analysis can proceed. An important limitation of this approach, however, is the absence of a clear and formal link to business strategy.

Therefore, the four kinds of decision problems that management may face in justification of new investment are detailed as follows:
4.2.3.1 Formal hierarchy

The first specification is described as the formal problem which is shown in Figure 4.1. In the formal hierarchy, the present worth (value) is the only criteria of interest. This is to be interpreted as meaning that the decision-maker is including in the decision only those factors that can be objectively measured in present value terms. For example; labour cost reduction and material cost savings.

The formal hierarchy problem is the traditional capital investment problem and is handled in the traditional manner using, for example, the nett present value computation.

Figure 4.1: Formal hierarchy problem
4.2.3.2 Economic value hierarchy

The second specification, which is the economic value problem, is shown in Figure 4.2. The economic value hierarchy is characterised by the consideration of quantifiable criteria other than those whose economic value has been measured. It is a simple AHP problem and includes both financial (NPV) and non-financial [economic environment (ENVIRONMENT), QUALITY and CUSTOMER] project selection criteria which can also be called "Basic AHP framework for capital budgeting" (Liberatore et al., 1992:34). Financial criteria could include, for example, net present value (NPV) or internal rate of return (IRR) and/or return on assets (ROA). Non-financial and non-quantitative criteria might include quality, flexibility and customer satisfaction.

Figure 4.2: Economic value hierarchy problem
A portion of the investment benefits can be quantified in financial terms, and therefore will be captured by traditional DCF analysis (that is, their effect will be incorporated into the project NPV, IRR, etc.). The computation of these factors, is usually arduous. In the economic value hierarchy problem, these criteria are measured and presented to the decision-maker in units of measure other than present worth (e.g. days, percentage of rejects, and so on).

An important issue to raise at this point is that criteria should be independent. Consider, for example, quality improvement. Quality improvement results in a cost saving due to less rework and scrap. It can also result in fewer defective products reaching the customer, thus improving customer satisfaction. The economic value of less rework and scrap is easier to measure than the economic value of improved customer satisfaction. The additional merit of the criteria labelled "quality improvement" is limited to that which is expected to occur from the second source alone. If the value of reduced rework and scrap has not been computed as part of the present worth calculation, then the value of other non-financial factors might not be computed in the present worth.

4.2.3.3 Value chain hierarchy

The third specification provides a linkage to the strategy process by utilising a specific planning theme or methodology in developing the AHP hierarchy. The value chain problem is shown in the Figure 4.3. This problem is characterised by the existence of one or more criteria for which there is no natural performance scale, or for which the values of each alternative on the performance scale are known. A good example of this approach is the application of Porter's value chain (1985).

A value chain is a graphic representation of the activities which add value as a product is transformed from raw material and delivered to the end user.

Patrovi (1990) has developed an AHP framework which first links the sub-criteria (competitive forces driving manufacturing) strategy with the activities in Porter's value chain (see Figure 4.3). In the second stage, individual projects are evaluated with respect to the impact on
the value chain, which is defined as threat of new entrants, intensity of rivalry among existing competitors, pressure from substitute products, bargaining power of buyers, and bargaining power of suppliers.

This second stage represent industry's competitive forces. Sustained profitability in any industry is determined by the degree of competition in that industry (Clarke et al, 1988:15).

Clarke et al (1988:15-16) added that:

strategic management of any firm must cope with competition and the industry forces generate it......

Finally, by combining the results across the levels of the hierarchy (Value chain hierarchy problem), the weight of individual technology projects on the firm's manufacturing strategy can be determined.

**Figure 4.3: Value chain hierarchy problem**

![Value chain hierarchy diagram]

Sources: Adapted from Patrovi (1990)
4.2.3.4 Planning hierarchy

The fourth specification requires explicit consideration of business objectives and strategies and follows a well-known approach for planning. This generic planning approach first requires developing the mission or charter of the firm. The mission is generally expressed as the maximization of owner's value within the context of providing certain products and services to select markets and customers.

The internal and external environments are analysed, and objectives are set. Finally, strategies and action plans are developed to achieve these objectives. Liberatore et al (1992:35) call this planning approach mission, objectives, strategies (MOS).

In applying MOS approach to capital budgeting, capital projects are viewed as part of the action plans necessary to achieve business strategies.

Capital projects are evaluated by criteria which are linked to the specific strategies undertaken by the firm. Since strategies contribute toward the achievement of business objectives and, in turn, the mission of the firm, a clear and formal link is then established between the capital budgeting and business planning process. The AHP can be used to quantify this linkage and here support the capital budgeting process. The planning problem shown in Figure 4.4 provides a generic framework for capital budgeting based on the MOS approach outlined above.

An important implication of the MOS capital budgeting framework presented in Figure 4.4 is that the relative importance of specifying evaluation criteria depends on the mix and relative importance of the strategies undertaken by a firm.

Consider now a firm that is making a strategic shift in emphasis toward upgrading its ability to compete on a technological basis. Factors such as flexibility and quality should have increased emphasis in the capital budgeting process. While this change may be generally agreed upon by the team responsible for making capital budgeting decisions, the real question is the degree to which the various evaluation criteria selected help support this
changing (and possibly unclear) notion of strategy.

Also, most firms typically pursue several strategies simultaneously, adding an additional degree of complexity. For example, this same firm may have a business maintenance strategy for some of its product lines. To support this maintenance strategy, more weight should be placed on standard financial criteria. This leads to a conflict with the competitive improvement strategy. To help determine the overall importance of multiple, and possibly conflicting, strategies a process is needed to help make such tradeoff explicit.

The capital budgeting within a MOS environment is well-suited for clarifying these issues.

**Figure 4.4: Planning hierarchy problem**

![Planning hierarchy problem diagram](source: Liberatore et al (1992:36))
4.3 THE SUBSTANTIVE COMPONENTS OF THE AHP HIERARCHY FOR CAPITAL BUDGETING

There are three substantive components of the AHP which were outlined in the above discussion namely; mission, objectives, and strategies (MOS). Each of these components will be described in the following sections.

4.3.1 Mission

The firm's mission is expressed by the development of its broad objectives. In generating investment ideas, decisions are not made in a vacuum, but rather with some objectives in mind. Throughout this dissertation, we operate on the assumption that the primary management mission or goal is to maximise the firm's value and that it is a reasonable operating objective upon which to build financial decision rules. There are, of course, other objectives: that managers who make actual decisions are interested in their own personal satisfaction, in employees' welfare and in the good of both their communities and society at large.

Welsch et al (1988:75) described the firm's mission as a "development of broad objectives". The statement of broad objectives should express the mission, vision and ethical character of the enterprise. Its purpose is to provide enterprise identity, continuity of purpose, and definition. One research study listed the purpose of the statement essentially as follows:

Firstly, to define the purpose of the company (to state exactly why the company is in business).
Secondly, to clarify the philosophy-character of the company (to state the moral ethical principles that guide actions).
Thirdly, to create a particular "climate" within the business.
Fourthly, to set down a guide for managers so that the decision they make will reflect the best interests of the business, with fairness and justice to those concerned.

The statement of broad objectives would normally not specify quantitative goals. Rather, it
should be a narrative expression of the purpose, objectives, and philosophical character of the business.

4.3.2 Objectives

The firm's objectives are called "specific goals for the enterprise" by Welsch et al (1988:77). The purpose is to bring the statement of broad objectives into sharper focus and to move from the realm of general information to more specific planning information.

The statement of specific goals can be, for example, to establish clearly:

I. Growth objective of the firm: a four percent annual increase in sales volume for the next five years. The new relevant factors influencing this growth plan can be described as follows:

   a. Product Z will be introduced at the beginning of 19X1.
   b. Two years hence, start entry into foreign market.
   c. An intensive market training program will be initiated during 19X2.
   d. Product pricing policies will not be changed.
   e. Aggressive and sophisticated sales efforts will be appropriately funded.

II. Return on total investment (ROI) objectives for the company will be 24 percent before tax. This ROI objectives should be realistic if:

   a. The sale plan is accomplished.
   b. Cost control objectives are realistically attained.
   c. Investment in assets is realistically planned and controlled.

III. Profit margin objectives are as follows:

   a. Overall company's profit margin is 15 percent before tax.
   b. Direct regional operating profit margin:
- Eastern 23 percent;  - Southern 24 percent;
- Northern 26 percent; - Western 23 percent.

There are numbers of specific goals that relate to the enterprise as a whole, and to a major responsibility centre which the firm can pursue. Note that the list above is not exhaustive.

4.3.3 Strategies

Company strategies are the basic thrusts, ways and tactics that will be used to attain planned objectives and goals. A particular strategy may be short-term or long-term. Here are some actual example of basic strategies:

1. Increase long-term market penetration, by using technology to develop new products and improve current products.
2. Emphasise product quality and price for "top" of the market.
3. Expand marketing worldwide.
4. Market with reasonable price to expand volume (units).
5. Use both institutional and local advertising programs to build market share.
6. Improve employee morale and productivity, by initiating a behaviour management program.

The purpose of developing and disseminating enterprise strategies is to find the best alternatives for attaining the planned broad objectives and specific goals. Strategies focus on "how"; therefore, they outline a plan of action for the enterprise. As the firm's mission, objectives and strategies (MOS), is described, let us go back to the main topic in order to see how the AHP copes with the MOS environment.
4.4 LINKING THE AHP IN A MISSION, OBJECTIVES AND STRATEGIES (MOS) ENVIRONMENT

The AHP can help management to link strategic aspects with capital budgeting environment through MOS, in order to evaluate the importance of the AHP method. An illustration is given below. It should be noted that the example given by Liberatore et al (1992:37-40) will be used because of its simplicity. The example will demonstrate how the AHP framework presented in Figure 4.4 can be applied in practice.

Let us consider a petrochemical firm as an example. Generally, most petrochemical firms are organised around three principal divisions, namely exploration division, refining and marketing (R&M), and chemicals. Throughout this illustration, we shall focus on the allocation process of one division only, which is refining and marketing (R&M). We will describe how R&M divisions could select projects utilising the AHP hierarchy, depicted in Figure 4.5, in order to guide our discussion.

It should be noted that Figure 4.5 will be explained throughout the following four sections.

Figure 4.5: AHP framework for capital budgeting for the Refining and Marketing (R&M) division of a petrochemical company.
4.4.1 Relating Refining and Marketing (R&M) Objectives to the Mission

It is important to relate R&M objectives to the stated corporate mission. In review of financial management notions, the corporate mission is always stated in terms of maximising the owner's wealth. For example, our Petrochemical firm can state its corporate mission as "to achieve a superior financial return, balanced with long term growth, benefiting owners...".

In each firm the mission is supported by the business objectives of the operating units, which must be detailed in the management's discussion of R&M operations in the companies' annual reports. As shown in Figure 4.5, these objectives include the following: market position, return on assets (ROA), environment, technology position, and customer focus. The individual target objectives vary from firm to firm. For example, firm A can state that one of the objectives for its R&M operation is to maintain a return on capital employed of 24 percent pretax in the long run. However, firm B can state that one of its major objectives is to restructure its foreign operations in order to improve efficiency and take advantage of opportunities arising from a unified European market in 1992. The proposed AHP framework is flexible enough to incorporate differences in specific objectives as well as their relative importance in achieving a division's mission.

The AHP method can now be used in order to prioritise these objectives through a series of pairwise comparisons of the importance of each objective in accomplishing R&M's mission. For example, management must determine the relative importance of return on assets (ROA) with respect to each other four objectives as stated in Figure 4.5 in meeting the goal of maximising owner's wealth.

4.4.2 Relating Strategies to Objectives

The next phase of the MOS planning process requires management to identify strategies needed to accomplish the previously stated objectives. The R&M strategies emphasised by most Petrochemical firms centred around the following issues:

S1. The degree of emphasis on heavy/sour vs. light/sweet laud in operations.
S2. The importance of alternative fuels.
S3. The need to improve the efficiency of refineries and/or stations.
S4. The modernisation of refinery equipment and/or stations.
S5. The degree of emphasis on international vs. domestic operations.

The relative importance of strategies incorporated into the AHP analysis can be adjusted to reflect the specific requirements of the corporation. For example, consider the importance of pursuing an international strategy (S5) by each of those two firms cited in Section 4.4.1. Firm B emphasises increased development of international R&M capacity as one strategy that can help to accomplish several objectives, especially market position and return on assets (see Figure 4.5).

On the other hand, Firm A concentrates its efforts on the local market, linking its efficiency (S3) and modernisation (S4) strategies with its customer focus objectives. Therefore, the international strategy is not as important to Firm A in accomplishing its stated R&M objectives.

In making operational strategy-objective relationships, the AHP requires that each of the strategies be compared with respect to their importance in achieving a given objective. Thus, one pairwise comparison matrix must be generated for each objective.

4.4.3 Relating projects to Strategies through criteria

The next phase of the AHP analysis requires linking actual capital budgeting decisions directly to the MOS framework. As mentioned earlier, capital projects make operational strategies that enable the firm to achieve its stated mission and objectives. Establishing the MOS project linkage requires identifying evaluation criteria which are closely aligned with each of the articulated business strategies. Given the mix of strategies described previously, it is evident that some non-financial and, possibly, even quantitative criteria must be included in the analysis. These evaluation criteria would be drawn from the three primary business functions: finance, marketing and manufacturing operations.
Consider again the two firms (A and B) in the example discussed earlier. A relevant set of criteria could include nett present value (NPV) or payback (PB) as financial factors, customer satisfaction as a marketing factor, and flexibility and throughput as operational factors (see Figure 4.5). For example, customer satisfaction could be measured as fuel delivery response time to service stations; flexibility as capability to process different varieties of crude processing rate (barrels/hour).

This set of five criteria cited above is not meant to be exhaustive but can be seen as being of primary concern to R&M operations in a petrochemical firm. It should be noted that a specific criteria can be supportive of more than one strategy. Once the criteria have been agreed upon, they must be compared pairwise to determine their relative importance in accomplishing each strategy. Next, specific capital projects that support the selected strategies must be identified. Of course, it is possible that a given capital project will support multiple strategies. This situation can easily be dealt within the AHP framework. Projects must then be compared pairwise with respect to those evaluation criteria associated with the strategies each project supports. The next example illustrates the linkage of the entire MOS process with project evaluation.

4.4.4 Linking project evaluation with the entire MOS planning process

Ultimately, the purpose of the entire framework is to link the individual project benefits to the overall mission of the firm. As discussed in the previous section, the capital projects are evaluated with respect to criteria which are closely aligned with specific business strategies. Referring back to our example of Firm B, consider two projects which support these environment objectives. The first proposed project (TANKS) targets the replacement of all service station underground steel tanks with new fibreglass (no-linking) tanks. The second project (CLEAN) proposes the development of a clean-burning alternative fuel.

The TANKS project supports the environment objective primarily through a modernisation strategy while the CLEAN project supports the same objective through the alternative fuel utilisation (S2) strategy.
These projects would be compared pairwise against other projects and against each other based on the criteria which would be important in evaluating the TANKS and CLEAN projects.

A key evaluation of criteria which the TANKS project supports is customer satisfaction. From this viewpoint the major benefit of the TANKS projects is the reduction of air and ground water pollution in the delivery of product to the customer. Thus, important dimensions of customer satisfaction are the degree of compliance with environmental regulations and a reduction in pollution.

Alternatively, a key driver in the evaluation of CLEAN project is the flexibility criterion. As environment pressures for cleaner air intensify, a cleaner burning fuel offers petrochemical companies additional flexibility in meeting the customer satisfaction criteria (as discussed above) since it will result in a reduction of air pollution.

Through this process of evaluating projects vis-a-vis appropriate criteria, one can determine the overall impact of both projects in utilising different strategies to achieve the environment objective.

Finally, the impact of these two projects on achieving the mission of the firm can be determined using the weights of the objectives provided by the AHP. Of course, it is possible that neither, one, or both of the investments could be funded depending on the firm's available resources.

4.5 CHAPTER SUMMARY

This chapter addresses the concern of practising managers about the tenuous linking between the capital budgeting process and strategic planning. The focus is on the fundamental problem of structuring the decision hierarchy appropriately so that the AHP can be implemented successfully in a capital budgeting context. Three approaches are presented for structuring AHP hierarchies, including the Mission, Objectives and Strategy (MOS) framework for strategic planning.
It is clear that the analytic hierarchy process, within an MOS environment, may be applied in business to link capital budgeting with the firm's strategy because of its simplicity.

All the literature necessary for strategic aspect in investment has been outlined and the next part of this dissertation deals with the empirical survey.
PART III

EMPIRICAL SURVEY
CHAPTER 5

THE METHOD OF RESEARCH

5.1 INTRODUCTION

In the earlier chapters, the theory of capital investment and general strategy, as well as the method selected to link the capital budgeting and the firm's strategy, have been outlined. The purpose of this chapter is to conduct an investigation concerning the use of the strategic aspects in investment decision-making by the South African manufacturers. Attention is now given to the research methodology used in the study.

In particular the following topics will be discussed:

* research design
* the size of the sample
* the method of sampling
* development of the research questionnaire
* representativeness of the response

5.2 RESEARCH DESIGN

A comparison of the most important sectors of economic activities of the South African economy with regard to their contribution to the gross domestic product (GDP) shows that the manufacturing sector made the largest contribution to GDP in all three years chosen. This is illustrated in Table 5.1.
Therefore, the manufacturing companies registered at the Bureau of Market Research (BMR) under the Standard Industrial Classification (SIC) were chosen as the target population of this study.

**TABLE 5.1:** Contribution of the Different Sectors to the Gross Domestic Product of the Country

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>15 586</td>
<td>19 802</td>
<td>18 779</td>
<td>4</td>
</tr>
<tr>
<td>Mining</td>
<td>30 505</td>
<td>33 172</td>
<td>33 305</td>
<td>8</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>81 167</td>
<td>90 177</td>
<td>104 474</td>
<td>24</td>
</tr>
<tr>
<td>Electricity</td>
<td>13 969</td>
<td>15 506</td>
<td>17 797</td>
<td>4</td>
</tr>
<tr>
<td>Construction</td>
<td>11 249</td>
<td>12 281</td>
<td>13 606</td>
<td>3</td>
</tr>
<tr>
<td>Trade and accommodation</td>
<td>55 699</td>
<td>61 450</td>
<td>70 094</td>
<td>16</td>
</tr>
<tr>
<td>Transport and communication</td>
<td>26 780</td>
<td>29 030</td>
<td>32 691</td>
<td>8</td>
</tr>
<tr>
<td>Financing and insurance</td>
<td>56 595</td>
<td>63 473</td>
<td>73 329</td>
<td>17</td>
</tr>
<tr>
<td>Public services</td>
<td>6 857</td>
<td>7 573</td>
<td>8 479</td>
<td>2</td>
</tr>
<tr>
<td>General government</td>
<td>40 299</td>
<td>44 674</td>
<td>49 011</td>
<td>12</td>
</tr>
<tr>
<td>Other producers</td>
<td>7 243</td>
<td>7 954</td>
<td>8 859</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>345 949</td>
<td>385 092</td>
<td>430 424</td>
<td>100</td>
</tr>
</tbody>
</table>


Table 5.1 indicates that in the three years under review the manufacturing sector made the greatest contribution to the GDP of the country. In 1995, for example, the contribution of the manufacturing sector was 24 percent in comparison with 17 from financing and insurance sector, and 16 percent from the trade and accommodation sector.

Martins *et al* (1996:441-442) advocate that:

The South African Central Statistical Service (CSS) has adapted the Standard Industrial Classification (SIC) to local conditions. The classification in the SIC is by type of economic activity and not by ownership, type of enterprise,..... .....Manufacturing, for instance, has been subdivided into ten divisions, 60 major groups (301 to 306), groups (3011 to 3053) and subgroups (30111 to 30530).

A further indication of the importance of the manufacturing sector is the variety of
subdivisions within the sector as well as the number of firms within each subdivision as illustrated in Table 5.2. The table shows that 33 percent of manufacturers found in South Africa deal in machinery, electrical transport and scientific equipment whereas 12 percent deal in textiles, clothing and leather substitutes; 11 percent deal in food, tobacco and beverages industries.

**TABLE 5.2:** Number of Manufacturers by Standard Industrial Classification (SIC) Code

<table>
<thead>
<tr>
<th>Type of manufacturer</th>
<th>SIC code</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-manufacturing head offices and holding companies</td>
<td>30</td>
<td>943</td>
<td>7</td>
</tr>
<tr>
<td>Food, beverages and tobacco</td>
<td>31</td>
<td>1648</td>
<td>11</td>
</tr>
<tr>
<td>Textiles, clothing and leather</td>
<td>32</td>
<td>1654</td>
<td>12</td>
</tr>
<tr>
<td>Wood and cork products</td>
<td>33</td>
<td>1132</td>
<td>8</td>
</tr>
<tr>
<td>Paper, printing and publishing</td>
<td>34</td>
<td>1064</td>
<td>7</td>
</tr>
<tr>
<td>Industrial chemicals, petroleum, coal and plastics</td>
<td>35</td>
<td>1368</td>
<td>10</td>
</tr>
<tr>
<td>Pottery, glass and other nonmetallic products</td>
<td>36</td>
<td>775</td>
<td>5</td>
</tr>
<tr>
<td>Iron, steel and nonferrous metal</td>
<td>37</td>
<td>260</td>
<td>2</td>
</tr>
<tr>
<td>Machinery, electrical transport and scientific equipment</td>
<td>38</td>
<td>4639</td>
<td>33</td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>39</td>
<td>642</td>
<td>5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td>14125</td>
<td>100</td>
</tr>
</tbody>
</table>


On investigation of the geographical dispersion of the manufacturers of South Africa, it is clear that the majority of manufacturers are located in the Gauteng region of the country. Table 5.3 illustrates that 46 percent of the total of 6 409 manufacturers fall into this region (Gauteng), as compared to 2 438 manufacturers in Kwazulu-Natal, which is classified as the second region and represents only 17 percent of the manufacturers.
TABLE 5.3: Number of Manufacturers by Geographical Region

<table>
<thead>
<tr>
<th>Geographical description</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western Cape</td>
<td>2 250</td>
<td>16</td>
</tr>
<tr>
<td>Eastern Cape</td>
<td>856</td>
<td>6</td>
</tr>
<tr>
<td>Northern Cape</td>
<td>192</td>
<td>1</td>
</tr>
<tr>
<td>Free State</td>
<td>472</td>
<td>3</td>
</tr>
<tr>
<td>Kwazulu-Natal</td>
<td>2 438</td>
<td>17</td>
</tr>
<tr>
<td>North West</td>
<td>483</td>
<td>4</td>
</tr>
<tr>
<td>Gauteng</td>
<td>6 409</td>
<td>46</td>
</tr>
<tr>
<td>Mpumalanga</td>
<td>442</td>
<td>3</td>
</tr>
<tr>
<td>Northern Province</td>
<td>265</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>318</td>
<td>2</td>
</tr>
<tr>
<td>TOTAL</td>
<td>14 125</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Bureau of Market research. The BMR Industrial Registers (1996:14)

Of the 6 409 manufacturing firms found in the Gauteng region, 424 manufacturers are non-manufacturing head offices and holding companies.

Because of the considerable contribution of the manufacturing sector to the country's economy, it was decided to use this sector as the universe for the study. Due to time and cost restraints, it was furthermore decided to limit the study to the region with the largest concentration of manufacturing firms, namely the Gauteng region.

5.3 THE SAMPLE SIZE

All manufacturers located in Gauteng region, regardless of type of product marketed or size of the firm, were included in the original population. The Standard Industrial Classification of industries (SIC), a classification system based on the International Standard Industrial Classification of all economic activities, was used in this study.

It was decided for practical purposes to limit the wide variety to nine main groups as outlined in Table 5.2. Non-manufacturing head offices and holding companies with an SIC code of 30 were to be left out of the population. This was to avoid the duplication of firms and to ensure the exclusion of some manufacturers (who do have head offices) in the drawing of
the sample. This left us with a total of 5 985 manufacturing firms in the Gauteng region.

The size of the firm can be determined by numerous means, for instance value of gross output, capital investment, or number of employees. The capital investment was chosen as method to measure the size of the firm for the purpose of analysing results.

In deciding upon the size of the sample practical considerations, namely reliability and accuracy of the results as well as time and cost constraints, had to be considered. This led to the decision to use a standard formula advocated by Kress (1988:189) to ascertain the size of the sample needed for the survey, the following formula is to be applied:

\[ n = \frac{P \times Q}{e^2 \left( \frac{P \times Q}{N} \right) + \left( \frac{P \times Q}{N} \right)} \]

where:
- \( n \) = the size of the sample
- \( P \) = the proportion of the sample that passes a given attribute
- \( q = 1 - P \)
- \( e^2 \) = the allowable error
- \( z \) = the standard deviation for a 95 percent confidence interval
- \( N \) = population size

The following assumptions were made regarding the above formula:
- \( P = 50 \text{ percent} \)
- \( q = 50 \text{ percent} \)
- \( e^2 = 5 \text{ percent} \)
- \( z = 1.96 \)
- \( N = 6 \, 409 \)

Because the value of 50 percent is assigned to \( P \) the maximum sample size needed for the desired degree of accuracy is guaranteed.

This action guarantees that the sample will be large enough to provide the desired confidence interval no matter what the real value of \( P \) might be (Kress 1988:189).

This also means that the researcher has a certainty of 95 percent that the results of sample will fall within five percent of the actual average of the relationship of the attributes \( p : q \).
Applying the various elements to the formula the following sample size was calculated:

\[ n = \frac{50 \times 50}{\left(\frac{5^2}{196^2}\right) \times (50 \times \frac{50}{6409})} = 361 \]

This result was reinforced by Krejcie and Morgan (1970:608) in their sample size table for proportions which reflects a sample size of 357 for a population of 5 000 and 361 for a population of 6 000, where the confidence level is set at 95 percent. With a population of 5 985 to draw from, every 17th record was chosen, resulting in a list of 361 firms. The Bureau of Market Research was contracted to provide a list of the names and addresses of the 361 firms in alphabetical order.

The aim of sorting by capital investment group was to ascertain whether there was any correlation between the amount invested by the firm and the techniques of capital budgeting used, an important goal of the research.

5.4 METHOD OF SAMPLING

The industrial register of South African manufacturers at the Bureau of Market Research is stored in a manner that allows a true random selection of the firms when drawing a sample.

According to the Bureau’s updated statistical program of 18/03/1996 the total number of South African manufacturers in the data bank was 14 125. The codes 71 to 78 of the Bureau’s statistical region codes represent the Gauteng region. These manufacturers totalled 6 409 firms at the time of the sampling.

After eliminating the companies with SIC code 30, namely 424 non-manufacturing head offices and holding companies, 5 985 records were left in the data bank.

The Bureau contracted to select the manufacturers for the sample according to the following criteria:
* all manufacturers had to be located in Gauteng;
* non-manufacturing head offices and holding companies had to be excluded;
* the sample had to be purely random;
* the capital investment had to be clearly indicated in order to assist with the analysis of results.

Since the names of the manufacturers in the Bureau's data bank are not sorted according to the size (number of employees or amount invested) of the company nor the type of activities, it was accepted that the selection procedure of the Bureau was random. Every 17th record was selected from the list of 5,985 manufacturers resulting in a sample size of 361.

A questionnaire was posted to the financial manager of each firm selected together with a covering letter explaining the purpose of the research and a self-addressed reply paid envelope for the respondent's convenience. The response received is detailed in section 5.6.

5.5 DEVELOPMENT OF THE QUESTIONNAIRE

The full text of the questionnaire appears as appendix A to this report and the general philosophy of the design is dealt with in this section.

It was felt that a factor of major importance in the design was the need to promote as high a degree of cooperation as possible from the informants. To this end, both the appearance and the content of the questionnaire were carefully considered. The questionnaire consisted of 7 pages which were photo reduced and stapled to form a small booklet of A5 size. The questions and instructions were laid out to ensure easy understanding by the respondents and answers were required based on a multiple-choice format.

A covering letter addressed to the financial manager was attached to the questionnaire explaining the objectives and importance of the research. The informants were not forced to identify themselves and they were assured that all information would be treated in the strictest confidence. A reply paid envelope was included with the questionnaire to ensure the
very minimum of inconvenience to the participants.

The questions themselves were designed to be simple: easy to answer without the respondent having to refer to other sources to obtain the requested information. Because the research was directed at top executives, who inevitably have many demands on their time, it was considered necessary to limit the length of the questionnaire so that it could be answered within fifteen minutes. It was, of course, imperative to ensure that useful data was forthcoming, as result of adopting this approach.

5.5.1 Questionnaire test

A preliminary questionnaire was compiled with a view to obtain as much information on methods used in order to consider strategic aspects without making the questionnaire too bulky. This resulted in a document of 30 questions (including five general questions) concentrating on the capital budgeting process, capital management practices and questions on the analytic hierarchy process method.

The preliminary questionnaire was discussed with three financial managers concerning strategic aspects in investment. The questionnaire was then adapted according to the suggestions made and we then ended up with 34 questions. The clarity, layout and coding of the questionnaire was discussed with a specialist at the Bureau of Teaching Development at the University of South Africa as well as numerous other researchers in the development of questionnaires. This was done to ensure that the results obtained in the survey could be processed and that these would meet the study's objectives.

5.5.2 Make-up of the questionnaire

The questionnaire was divided into five sections which were structured to elicit information in a logical order of increased focus on the research objectives.

Section 1 consists of five questions of a general nature, the objective of which was to obtain an overview of the characteristics of the responding firms in terms of size and type of products manufactured by the firm.
Section 2 of the questionnaire consisted of two questions which were a brief inquiry into the approximate value of the firm's capital investment and turnover.

Section 3 contained 16 questions and had the objective of establishing how companies dealt with strategic aspects in investment decisions. Ten of the questions were intended to elicit information concerning the firms' attitudes towards strategic aspects. Information sought included:

* capital budgeting process
* origin of investment opportunities
* amount of time spent on evaluating investment ideas
* capital budgeting techniques and weighted average cost of capital
* non-financial factors in investment decision.

Section 4 concluded the questionnaire with 10 questions designed to show the attitudes of informants towards the awareness of an extended method for strategy analysis, called analytic hierarchy process (AHP).

Finally one question requiring their comments concerning strategic aspects in investments decision-making was included.

5.5.3 Method of Data Analysis

The data from the completed replies were computerised onto a worksheet and summarised in order to group the data into four capital intensity strata. The data were analysed using statistical formulas to compute means, percentages and standard deviations, which were necessary for each capital intensity stratum. An analysis of the total sample was also performed in order to compare the aggregated results with previous research studies.

5.6 REPRESENTATIVENESS OF THE RESPONSE

Of the 361 questionnaire posted to respondents, 153 were returned and 150 were satisfactorily completed. This represents a response rate of 42 percent.
Meyburg (1979: 112-114) point out the following:

In self-administered surveys, the biggest problem is usually non-response. In most reports dealing with past experience on this type of survey, average non-response is frequently quoted as being in the order of 70% ...

Kerlinger (1986: 380) has a similar opinion on the matter of response rates:

Responses to mail questionnaires are generally poor. Returns of less than 40 to 50 percent are common. Higher percentages are rare.

The response rate achieved in the survey is thus in line with what can be expected from a postal survey. Furthermore, this is no reason to believe that the questions contained in the questionnaire would cause bias in the answers received. The response was, therefore, considered to be acceptably representative of the population.

Out of 44 firms approached telephonically to complete the survey, 26 firms were uncooperative with the main reason "do not have time", and two questionnaires were marked "not a manufacturing concern".

5.7 CHAPTER SUMMARY

The object of the study was to assess the current state of capital budgeting practice in manufacturing industry in South Africa. The BMR Industrial Register served as the sample frame for the study. The universe consisted of 14,125 establishments in the manufacturing sector. A disproportionate stratified random sample of 361 establishments was drawn by type of establishment and employment size group. Usable questionnaires were returned by 153 establishments, which meant that a response rate of 42.4% was attained in the survey. All the results were weighted for purposes of calculating totals.

The questionnaire used for the postal survey underwent numerous adjustments during the development phase and the analysis of results will now be discussed.

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CHAPTER 6

ANALYSIS OF RESULTS

6.1 INTRODUCTION

The purpose of this chapter is to analyse the data obtained from the 153 respondents. The results were tabulated according to the nature and capital invested by manufacturers situated in Gauteng region of South Africa. Special attention will be given to ascertaining the extent of theory and techniques of using strategic aspects in investment decision-making, any correlation between size and type of respondents and selected techniques used, as well as common reasons for not using specific techniques will be discussed in this chapter. The frequencies of respondents can be found in Appendix C.

6.2 THE STATISTICAL ANALYSIS OF RESULTS

From the 153 respondents, three questionnaires were almost blank (without sufficient information) which led us to focus on 150 firms only. However, the statistical analysis of results will cover the following topics:

- type and size of manufacturer
- capital invested
- capital investment process
- origin of investment opportunities
- management of time spent on project analysis
- investment management techniques
6.2.1 Type and size of manufacturers

To obtain clarity on the type and size of firms represented in the sample, attention was given to:

- the nature of the industry,
- the number of employees per firm, and
- the capital invested.

6.2.1.1 Type of industry

A frequency distribution was undertaken classifying the respondents according to primary economic activity, the results of which appear in Table 6.1. It is apparent from the table that responses were received from all areas of the manufacturing sector, with the majority of the responses (29 percent) from the machinery, electrical transport and scientific equipment activities. This is representative of the statistics in Table 5.2 which reflect the highest percentage (33 percent) of the manufacturers according to the standard industrial classification (SIC).

In order to correlate any similarities in trends between type of manufacturer and particular strategic methods, the primary economic activities were combined into four groups of reasonable sizes, as shown in Table 6.1. This was done because a number of the activities had frequencies that were too small for meaningful comparison or analysis, for example textiles, clothing and leather with a frequency of 3 percent. Therefore, "Machinery, electrical transport and scientific equipment" with 44 respondents, was classified as Group 1; "Industrial chemicals, petroleum, coal and plastics" with 29 respondents, as Group 2; "Iron, steel and nonferrous metal" with 16 respondents, as Group 3; and all the other groups, with a total of 61 respondents, as Group 4.
Table 6.1: Frequencies Distribution according to the Primary Economy Activity

<table>
<thead>
<tr>
<th>Primary economic activity</th>
<th>Frequency</th>
<th>%</th>
<th>Grouping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food, beverage and tobacco</td>
<td>5</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Textiles, clothing and leather</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Wood and cork products</td>
<td>8</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Paper, printing and publishing</td>
<td>15</td>
<td>10</td>
<td>4</td>
</tr>
<tr>
<td>Industrial chemicals, petroleum, coal and plastics</td>
<td>29</td>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>Pottery, glass and other nonmetallic products</td>
<td>6</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Iron, steel and nonferrous metal</td>
<td>16</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Machinery, electrical transport and scientific equipment</td>
<td>44</td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>23</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>150</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

6.2.1.2 Number of employees per firm

Graph 6.1 illustrates the frequency distribution of the respondents according to the firm's number of employees. The results from Graph 6.1 show that 34 of the respondents came from firms with 20 to 49 employees which represents 22.5 percent of responses.

Graph 6.1

Frequency according to number of employees
Combining these results, it is apparent that the largest response of 77.5 percent came from firms with 10 to 399 employees. This shows that mainly large firms were willing to participate in this study.

6.2.1.3 *Capital invested*

A frequency distribution was undertaken classifying the respondents according to the capital invested, the result of which appears in Table 6.2, showing that 38 percent of responses were received from firms whose investment in assets exceeded R5 000 000. In other words, the results received from large firms was far better than from small firms. For instance, there is only 6 percent from firms with investment up to R100 000. This confirms once more that only large firms were a willing to send back questionnaires mailed to them.

Table 6.2 indicates distribution of the amounts invested and the new selected range.

**Table 6.2: Frequency Distribution of Amount Invested by Firms and New Selected Range**

<table>
<thead>
<tr>
<th>CLASSIFICATION</th>
<th>FREQUENCY</th>
<th>PERCENTAGE</th>
<th>NEW RANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; R30 000</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>R30 001 - R100 000</td>
<td>8</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>R100 001 - R500 000</td>
<td>34</td>
<td>23</td>
<td>2</td>
</tr>
<tr>
<td>R500 001 - R1 000 000</td>
<td>17</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>R1 000 001 - R5 000 000</td>
<td>32</td>
<td>22</td>
<td>4</td>
</tr>
<tr>
<td>R5 000 001+</td>
<td>57</td>
<td>38</td>
<td>4</td>
</tr>
</tbody>
</table>

As our topic focuses on the capital investment decision, the amount invested by the firm is very helpful in order to determine the size of the firm. For the same reason companies were broadly classified into four ranges of capital invested. Firms which invested an amount of less than R100 000 are classified as Group 1; for R100 001 to R500 000 as Group 2; for R500 001 to R1 000 000 as Group 3; and for R1 000 001 and above as Group 4.
6.2.2 Capital investment process

In the analysis of the investment process used by respondents, Graph 6.2 illustrates that 84 of the respondents, which represents 53 percent, prefer financial evaluation, 35 of the respondents, 23 percent of the respondents use identification and generation of ideas and only 22 respondents (14 percent) prefer strategic evaluation in order to make investment decision.

Graph 6.2:

**Frequency according to investment process**

![Graph showing frequency distribution of investment processes](image)

6.2.3 Origin of investment opportunities

Table 6.3 shows that 95 percent of the respondents indicated that their investment opportunities are identified by top management, 4 percent of the investment opportunities are identified by the middle management and 1 percent by others.
Table 6.3: Frequency of the Origin Investment Opportunities

<table>
<thead>
<tr>
<th>CLASSIFICATION</th>
<th>FREQUENCY</th>
<th>PERCENTAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top management</td>
<td>143</td>
<td>95</td>
</tr>
<tr>
<td>Middle management</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

6.2.4 Allocation of time spent on projects

An analysis of time allocated by respondents is shown in Figure 6.1. It reveals that the majority (59 percent of respondents) spent less than ten percent of their time on evaluating investment ideas. Similarly, Figure 6.2 shows that the majority (73 percent of respondents) spent less than 10 percent of their time to evaluate acceptable investment proposals. This confirms why only 14 percent of the respondents consider strategic aspects as their most important step in capital investment decision-making (refer to Graph 6.2). A number of respondents commented that with the economic recession at the time of the survey, capital investment had not been undertaken; nor did they foresee funds available for investment for the immediate future. Only two respondents indicated that they spent more than 60 percent of their time both on evaluating investment ideas and acceptable investment proposals.

Figure 6.1: Percentage according to the time spent on projects evaluation

<10% 59.6%
22.2%
10-19%
12.1%
40-59%
60%+
20-39%

Time spent
- <10%
- 10-19%
- 20-39%
- 40-59%
- 60%+
6.2.5 Investment techniques management

The analysis of the investment techniques used by respondents shown in Table 6.4, illustrates that the payback period technique has the highest frequency, indicating that it an important investment technique used by the respondents. This is followed by the NPV as second and ARR as third decision rules (techniques) used by the respondents in order to evaluate their investment proposals (refer to Appendix C, Tables C7 and C8). It was observed that most respondents spend less than ten percent of their time on project evaluation and more than 50 percent of the respondents make use of at least one of the generally known capital budgeting techniques.
Table 6.4: Frequency Distribution according to the Investment Techniques

<table>
<thead>
<tr>
<th>TECHNIQUES</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payback period</td>
<td>69</td>
</tr>
<tr>
<td>ARR</td>
<td>50</td>
</tr>
<tr>
<td>NPV</td>
<td>57</td>
</tr>
<tr>
<td>IRR</td>
<td>42</td>
</tr>
<tr>
<td>PI</td>
<td>43</td>
</tr>
</tbody>
</table>

6.2.6 Concepts related to capital investment techniques

The weighted average cost of capital is the most important concept related to capital investment techniques in order to evaluate the investment. It is used to calculate the combination of the estimated costs of the various capital components (Brigham and Gapenski, 1990:152). The weighted average cost of capital is one of the more difficult capital budgeting components to capture with accuracy.

Although, the weighted average cost of capital is difficult to compare with accuracy, it was used by 43 percent of respondents (refer to Appendix C, Tables C15 and C16), the greatest use being made by respondents from the Machinery, electrical transport and scientific equipment with 15 percent, followed by Industrial chemical, petroleum, coal and plastic with 50 percent. The most common reasons for not calculating the weighted average cost of capital were “do not need it”, other respondents felt that they are unfamiliar with it.

Thirty-three percent of respondents found the techniques of capital budgeting easy, 20 percent found it “purely academic”, and 19 percent “sophisticated” (refer to Appendix C, Table C17). Although a great percentage (33 percent) of respondents do use techniques of capital budgeting, 5 percent of these respondents found it “very difficult” and 12 percent found it “impractical.”
6.2.7 Consideration of strategic aspects

In analysing the use of strategic aspects by respondents, it appears that 92 percent of the respondents do take quantifiable, as well as non-quantifiable, factors into consideration when making investment decisions (refer to appendix C, Table C19). Only 4 percent of the respondents do not incorporate non-quantifiable factors in their investment decision making. Out of the 92 percent of respondents who do take into consideration quantifiable as well non-quantifiable factors, 47 percent of them “always” incorporate quantifiable as well as non-quantifiable factors in investment decisions, 49 percent do so “sometimes”, and 4 percent “never” incorporate quantifiable as well as non-quantifiable factors in investment decision making. Being a small firm was the main reason for the firms who do not consider non-quantifiable factors in their investment decision.

Similarly, 87 percent of the respondents do incorporate non-financial factors into their investment decision (refer to Appendix C, Table C20). The most common reason for not incorporating non-financial factors was that respondents felt that they are too small to consider non-financial factors into their investment decision. Out of the 87 percent of respondents who do incorporate non-financial factors into their investment decision, 74 percent of them “sometimes” incorporate non-financial factors in their investment decision, and only 17 percent “always” incorporate non-financial factors in their investment decision.

The high percentages of 92 percent and 87 percent received from respondents to questions 18 and 21 (refer to Appendix B), may be because the respondents misunderstood the context of those questions, by which were meant “if they do use both factors, respectively quantifiable and non-quantifiable factors, and financial and non-financial factors”, and not one of the two factors.

6.2.8 Analytic hierarchy process (AHP) awareness

Only six out of a total of 153 respondents were aware of the analytic hierarchy process (refer to Appendix C, Table C22), which represents four percent of the respondents. The highest percentage (nine percent) of respondents came from other manufacturing firms.

The AHP is a method that may provide a consistent methodology that helps to link strategic
priorities with investment decisions (Liberatore et al., 1992:32). None of the responding firms use the AHP method in practice. Two of the respondents judge the AHP method impractical and one judges it sophisticated, whereas 50 percent of the respondents (refer to Appendix C, Table C25) agree that the AHP method may help in investment decision, and 50 percent do not agree that the AHP method may help in investment decision.

Two respondents (refer to Appendix C, Table C26) believe that the AHP method must be used to the strategic evaluation of the capital budgeting, whereas one respondent believes that the AHP method must be used to the identification phase of the capital budgeting process, and another respondent believes that the AHP method must be used to the identification phase of the capital budgeting process.

In order to know how the AHP method may help link capital budgeting to the firm's strategy (refer to Appendix C, Table C27), two respondents felt that the AHP method may "usually" help link capital budgeting to the firm's strategy, one respondent felt that the AHP method may "sometimes" help link capital budgeting to the firm's strategy, and an other respondent felt that the AHP method "never" helps link capital budgeting to the firm's strategy.

One respondent (refer to Appendix C, Table C28) believes that the AHP method is "good" in order to help in investment decision, whereas another respondent believes that the AHP method is "poor" in order to help in investment decision.

Since such a small percentage responded to the AHP questions, the above comments cannot be seen as very representative.

6.3 CROSS-TABULATION BY TYPE AND SIZE OF INDUSTRY

In an effort to identify any common use of strategic aspects in investment decision-making according to type and size of manufacturers, further statistical tests were undertaken. Contingency table analysis using the chi-square statistic is frequently used in order to determine whether two nominal measures are related. This was done by organizing the data into a contingency table and then observing cell frequencies in order to compare them with those that would be expected in the absence of any significant statistical relationship between
the measures (Moore and Reicher, 1983:631).

After organizing the data into contingency tables, many cell frequencies were so small that the chi-square statistics were unreliable. However, the frequencies in the two-way tables also tell a story and we will make some comments on it. The general findings of this analysis will now be discussed in the following sections.

6.3.1 Cross-tabulation by type of industry

Cross-tabulations by type of manufacturers (Groups 1 to 4), and various strategic aspects were done. As mentioned earlier in Section 6.2.1.1, firm types were classified into four groups of reasonable response size which are listed as follows:

GROUP 1: Machinery, electrical transport and scientific equipment
GROUP 2: Industrial chemicals, petroleum, coal and plastics
GROUP 3: Iron, steel and nonferrous metal
GROUP 4: Food, beverage and tobacco; Textiles, clothing and leather; Wood and cork products; Paper, printing and publishing; Pottery, glass and other nonmetallic products; and other manufacturing firms

Table 6.5 represents a cross-tabulation of the manufacturer type with capital budgeting process.

Table 6.5: Percentage Use of the Capital Budgeting Process by the Manufacturer's Type

<table>
<thead>
<tr>
<th>TYPE/STRATEGY</th>
<th>PROJECT IDENTIFICATION</th>
<th>STRATEGIC EVALUATION</th>
<th>FINANCIAL EVALUATION</th>
<th>AVERAGE %</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>29</td>
<td>14</td>
<td>18</td>
<td>20</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>9</td>
<td>27</td>
<td>7</td>
<td>14</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>29</td>
<td>27</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>34</td>
<td>32</td>
<td>47</td>
<td>38</td>
</tr>
</tbody>
</table>
Table 6.5 shows that the capital budgeting process was used by the majority of respondents and the financial evaluation was selected as the most important phase, being used by 47 percent of the respondents in Group 4. In Group 2, 27 percent chose the strategic evaluation process as the most important, and the identification and financial evaluation process as relatively unimportant (nine and seven percent respectively).

The average percentage usage of the capital budgeting process by the manufacturer's type shows that Group 4, with 38 percent, made the most use of the capital budgeting process.

Table 6.6: Percentage Use of Strategic Consideration by the Manufacturer's Type

<table>
<thead>
<tr>
<th>TYPE/PROCESS</th>
<th>TOP MANAGEMENT</th>
<th>NON-QUANTIFIABLE</th>
<th>AHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>93</td>
<td>97</td>
<td>3</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>94</td>
<td>87</td>
<td>6</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>100</td>
<td>91</td>
<td>2</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>93</td>
<td>93</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 6.6 shows the percentage use of the investment opportunities origin, time spent in evaluating non-quantifiable factors and awareness of analytic hierarchy process method according to the nature of the industry. More than 90 percent of respondents from all groups reported that their investment opportunities come from the top management, with 100 percent in Group 3. The non-quantifiable factors were also taken into consideration by more than 87 percent of respondents, with Group 1 being the largest user of non-quantifiable factors in investment, namely 97 percent. Concerning the awareness of the AHP, there were very few respondents who were aware of the method, with the greatest percentage being only six (reported by Group 2).
Table 6.7: Percentage Use of the Capital Budgeting Techniques by the Manufacturer's Type

<table>
<thead>
<tr>
<th>TYPE/TECHNIQUES</th>
<th>PAYBACK</th>
<th>ARR</th>
<th>NPV</th>
<th>WACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>GROUP 1</td>
<td>50</td>
<td>39</td>
<td>47</td>
<td>48</td>
</tr>
<tr>
<td>GROUP 2</td>
<td>60</td>
<td>20</td>
<td>27</td>
<td>44</td>
</tr>
<tr>
<td>GROUP 3</td>
<td>50</td>
<td>43</td>
<td>45</td>
<td>51</td>
</tr>
<tr>
<td>GROUP 4</td>
<td>41</td>
<td>31</td>
<td>34</td>
<td>34</td>
</tr>
</tbody>
</table>

Table 6.7 shows the percentage use of the capital budgeting techniques by the manufacturer's type. The payback technique was the technique most used (60 percent) by the respondents in Group 2, while Group 3 made the highest percentage (51 percent) for WACC technique.

The manufacturer's type stratification tables clearly indicate that no particular group of industries markedly used more components of strategic aspects, namely the three first phases of the capital budgeting process; investment opportunities; consideration of non-quantifiable factor into the investment decision; awareness of the AHP method; and investment techniques. The results obtained change according to the components used.

It would seem that despite the unknown AHP method, the most under-utilized areas or component of strategic aspects were the capital budgeting process and the capital budgeting techniques. The reasons given most often by respondents for not using investment techniques were that they found the techniques "purely academic" and "sophisticated" (refer to Appendix C, Table C16).

6.3.2 Cross-tabulation by size of industry

In order to facilitate the interpretation of the results obtained from the respondents in this particular section, the industry's size was reduced to four classifications, which are listed as follows:
GROUP 1: Less than R30 000  
GROUP 2: R30 001 - R100 000  
GROUP 3: R100 001 - R500 000  
GROUP 4: R500 000+

Table 6.8 is a cross-tabulation of the capital budgeting process by the size of industry.

**Table 6.8:** Percentage Use of the Capital Budgeting Process by Manufacturer's Size

<table>
<thead>
<tr>
<th>SIZE/PROCESS</th>
<th>PROJECT IDENTIFICATION</th>
<th>STRATEGIC EVALUATION</th>
<th>FINANCIAL EVALUATION</th>
<th>AVERAGE %</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; R30 000</td>
<td>3</td>
<td>8</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>R30 001 - R100 000</td>
<td>24</td>
<td>26</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>R100 001 - R500 000</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>R500 000+</td>
<td>63</td>
<td>56</td>
<td>63</td>
<td>61</td>
</tr>
</tbody>
</table>

Table 6.8 shows that the small firms made less use of capital budgeting process, and the bigger the firms become, the more they make use of the capital budgeting process. However, identification of ideas and financial evaluation were the processes most used (63 percent) by the firms which invested more than R5 000 000, classified as Group 4.

Table 6.9 is a cross-tabulation of strategic consideration by manufacturer's size. It shows that the top management of more than 93 percent of the respondents identify investment opportunities. It is interesting to note that in Group 4 (firms which invested more than R5 000 000) only 93 percent of the respondents reported that their investment ideas or opportunities come from the top management compared to other groups in which more than 97 percent of the respondents reported that their investment ideas come from the top management. This means that the Group 4 firms also consider the investment ideas from other levels of the organization.
According to table 6.9, more than 80 percent of the respondents do consider non-quantifiable factors in their investment decision, the greater percentage, namely 97 percent, was made by firms with capital investment range from R30 001 to R100 000, classified as Group 2. Regarding awareness of the AHP method, a small percentage of the respondents were aware of the AHP method. Table 6.9 indicates that only large firms were aware of the AHP method, small firms were not at all aware of the AHP method. It is interesting to note that the greatest percentage of awareness of the AHP method was recorded for the firms with capital invested in the range from R100 001 to R5 000 000, namely Group 3.

Table 6.10 reflects the percentage use of capital budgeting techniques by the manufacturer's size. The table indicates that no group made use of more than 50 percent of the investment techniques. However, the percentage use of the payback method grows according to the manufacturer's size. Conversely, the highest percentage use, namely 50 percent, of ARR technique was made by firms which had less than R30 000 invested capital, classified as Group 1.

Table 6.10: Percentage of Use of Investment Techniques by Manufacturer’s Size

<table>
<thead>
<tr>
<th>SIZE/TECHNIQUES</th>
<th>PAYBACK</th>
<th>ARR</th>
<th>NPV</th>
<th>WACC</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; R30 000</td>
<td>25</td>
<td>50</td>
<td>25</td>
<td>44</td>
</tr>
<tr>
<td>R300 001 - R100 000</td>
<td>47</td>
<td>38</td>
<td>41</td>
<td>41</td>
</tr>
<tr>
<td>R100 001 - R500 000</td>
<td>47</td>
<td>27</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>R500 000+</td>
<td>48</td>
<td>33</td>
<td>41</td>
<td>47</td>
</tr>
</tbody>
</table>
From the manufacturer's size stratification tables, it would seem that, the larger the firm, the greater the percentage of strategic aspects used in investment decision.

6.3.3 Classification of results by type and size of industry

The results received from the respondents were classified by the frequency tables according to the type and size of industry.

The frequencies of each strategic component were totalled and then ranked according to the importance given by the respondents. In other words, strategic components were ranked according to the highest total frequency.

6.3.3.1 Ranking of the results by the industry type

Table 6.11 shows the frequency of ranking the strategic aspects in investment decisions by the firm type. It appears that the top management has the highest frequency and was ranked as the first component of the strategic aspects in investment decisions used by the manufacturers. This means that top management was considered the most important aspect of strategy according to the type of the industry. Even though, the manufacturer's management spent less than ten percent of their time in evaluating the project, non-quantifiable factors were also taken into account in their investment decision-making.

Non-quantifiable factors were ranked as the second strategic components in investment decision-making used by the firm type. This was followed by the financial evaluation ranked third in the strategic components in investment decision-making used by the firm type.
Table 6.11: Ranking of Frequency of the Strategic Components by the Manufacturer’s Type

<table>
<thead>
<tr>
<th>COMPONENTS/TYP</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>TOTAL</th>
<th>RANK</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. PROCESS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Identification</td>
<td>10</td>
<td>3</td>
<td>10</td>
<td>12</td>
<td>35</td>
<td>8</td>
</tr>
<tr>
<td>2. Strategic evaluation</td>
<td>3</td>
<td>6</td>
<td>6</td>
<td>7</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>3. Financial evaluation</td>
<td>15</td>
<td>6</td>
<td>23</td>
<td>39</td>
<td>83</td>
<td>3</td>
</tr>
<tr>
<td>II. STRATEGY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Top management</td>
<td>27</td>
<td>15</td>
<td>43</td>
<td>57</td>
<td>142</td>
<td>1</td>
</tr>
<tr>
<td>2. Non-quantifiable</td>
<td>28</td>
<td>13</td>
<td>39</td>
<td>57</td>
<td>137</td>
<td>2</td>
</tr>
<tr>
<td>3. AHP</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>III. TECHNIQUES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Payback</td>
<td>14</td>
<td>9</td>
<td>20</td>
<td>24</td>
<td>67</td>
<td>4</td>
</tr>
<tr>
<td>2. ARR</td>
<td>11</td>
<td>3</td>
<td>17</td>
<td>18</td>
<td>49</td>
<td>7</td>
</tr>
<tr>
<td>3. NPV</td>
<td>13</td>
<td>4</td>
<td>18</td>
<td>20</td>
<td>55</td>
<td>6</td>
</tr>
<tr>
<td>4. WACC</td>
<td>14</td>
<td>7</td>
<td>22</td>
<td>21</td>
<td>64</td>
<td>5</td>
</tr>
</tbody>
</table>

6.3.3.2 Ranking of the results by the industry size

When ranking the results in order of importance according to the size of the firms, Table 6.12 shows that the top management was considered the most important strategic component in investment decision-making by the large manufacturers during the time of survey. Non-quantifiable factors was ranked second, followed by the financial evaluation.
### Table 6.12: Ranking of Frequency of the Strategic Components by the Manufacturer's Type

<table>
<thead>
<tr>
<th>COMPONENTS/ SIZE</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
<th>TOTAL</th>
<th>RANK</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. PROCESS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Identification</td>
<td>1</td>
<td>5</td>
<td>3</td>
<td>25</td>
<td>34</td>
<td>8</td>
</tr>
<tr>
<td>2. Strategic evaluation</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>16</td>
<td>22</td>
<td>9</td>
</tr>
<tr>
<td>3. Financial evaluation</td>
<td>7</td>
<td>24</td>
<td>10</td>
<td>43</td>
<td>84</td>
<td>3</td>
</tr>
<tr>
<td><strong>II. STRATEGY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Top management</td>
<td>8</td>
<td>33</td>
<td>15</td>
<td>79</td>
<td>135</td>
<td>1</td>
</tr>
<tr>
<td>2. Non-quantifiable</td>
<td>7</td>
<td>33</td>
<td>12</td>
<td>81</td>
<td>133</td>
<td>2</td>
</tr>
<tr>
<td>3. AHP</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td><strong>III. TECHNIQUES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Payback</td>
<td>2</td>
<td>16</td>
<td>7</td>
<td>41</td>
<td>66</td>
<td>4</td>
</tr>
<tr>
<td>2. ARR</td>
<td>4</td>
<td>13</td>
<td>4</td>
<td>28</td>
<td>49</td>
<td>7</td>
</tr>
<tr>
<td>3. NPV</td>
<td>2</td>
<td>14</td>
<td>4</td>
<td>35</td>
<td>55</td>
<td>6</td>
</tr>
<tr>
<td>4. WACC</td>
<td>4</td>
<td>14</td>
<td>4</td>
<td>42</td>
<td>64</td>
<td>5</td>
</tr>
</tbody>
</table>

### 6.4 CHAPTER SUMMARY

This statistical analysis of the survey data reveals that the top management was considered as the most important strategic component used by both type as well as size of industry in their investment decision-making. The financial evaluation was the investment process used the most by the respondents. Very few of the respondents used strategic evaluation (ranked 9 and 8 respectively, in the type and the size of the industry) in their capital budgeting process. Although the majority of the respondents were not aware of the AHP method, however, more respondents seemed to take into consideration non-quantifiable factors in their investment decision-making.

The firm’s size stratification analysis generally revealed that the larger the firm, the greater the percentage of use of strategic aspects in their investment decision-making. Whereas the
firm's type stratification did not reveal any marked use of particular strategic component in any one group.

Having analysed the results, the next and final chapter presents a summary of the research followed in this study, as well as conclusions drawn and recommendations made on the findings.
CHAPTER 7

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1 INTRODUCTION

In this chapter a brief summary is given of what this study set out to achieve, how the research was carried out and what the findings of the survey were. Thereafter conclusions are drawn on the study and recommendations made for future research in this area.

7.2 SUMMARY

This study set out to examine the use of strategic considerations in the investment decision making process of South African manufacturers operating in the Gauteng region. Chapter One presented an overview of the research, defining the objectives and scope of the study.

Three objectives were specified. The first objective was to determine the most used phase of the capital budgeting process which South African manufacturers prefer in their investment decision making, and whether there is consideration of strategic aspects in their investment decision making. The second objective was to establish whether there is a correlation between size and type of manufacturers and the use of strategic planning. The third objective was to gauge the reasons for manufacturers not making use of strategic planning in their investment decision-making.

The literature study consisting of three chapters was then undertaken. Chapter Two covers the capital investment process. The four phases of the capital investment process and capital budgeting techniques were in turn outlined. Attention was focused on the planning
and evaluating phase, which is the identification of investment ideas and project evaluation. The deficiencies of the relevant theory of capital budgeting in contrast to practice was also discussed.

Chapter Three covered strategic aspects in investment. The role of strategy in investment was outlined, followed by the development of components which strongly affect the firm’s activities in the short and long run. Amongst others the following were studied: competitive forces, the type of strategy and the three generic strategies.

Chapter Four outlined the method for linking capital budgeting with the firm’s strategy. Here the theory of the analytic hierarchy process (AHP) method was outlined, followed by its three components, namely mission, objectives and strategies (MOS) environment, which help link investment decisions to the firm’s strategy.

Chapter Five set out the methodology, followed by the empirical research. Determination of the research area, size and method of sampling, as well as the development of the questionnaire were discussed. Finally, the representativeness of the responses was considered before presenting an analysis.

Chapter Six presents the results of the research: the analysis revealed that financial evaluation was overwhelmingly the most popular phase in the capital budgeting process used by the respondents, while strategic planning was used by a small percentage of the respondents (refer to Appendix C, Table C5). Respondents were sometimes incorporating non-financial factors into their investment decision making. Finally, only a small number of the respondents were aware of the analytic hierarchy method.

Having briefly outlined what the study set out to do and the method followed to achieve the objectives, detailed conclusions may be drawn on the findings.

7.2 CONCLUSIONS

Based on the limited sample size upon which this research was carried out, the following conclusions may be drawn:
Responses were received from all areas of the manufacturing sector as shown on Table 6.1, with the majority from the machinery, electrical, transport and scientific equipment activities. Here it was concluded that the response obtained was from a reasonable cross-section of the population.

Response from firms with capital investment of more than R100 000 was far better than that from smaller firms, the last cited are limited in their ability to utilize the capital budgeting process and sophisticated financial techniques.

In reply to the first research objective of this study, which is to determine the different phases of the capital investment process used by the South African manufacturers, it would appear from graph 6.2 that the majority of respondents consider financial evaluation as an essential phase of their capital budgeting process for investment decision-making. This last statement was also clearly explained in the analysis of time spent on non-financial factors, in which most of respondents spent less than ten percent of their time for investment ideas and for non-financial factors in their investment decision-making.

This led us to confirm with Affect et al (1986:17) that South African manufacturers use the discounted cash flow (DCF) models, they give more weight to tangible and quantitative factors, though they also consider other intangible and qualitative factors.

It should be noted that the last statement might reveal that the respondents misunderstood the context of Questions 18 and 21, in which was meant "if they do use both factors, respectively quantifiable and non-quantifiable factors, and financial and non-financial factors", and not one of the two factors.

However, as earlier indicated in Chapter Two, Mukherjee and Henderson (1987:85) state that:

contrasting capital budgeting practices with theory reveals a number of differences. This is most apparent in the selection, which has been a primary focus of financial theory and is the most closely examined aspect of business practice...

Therefore, the above statement relating to the literature of the capital budgeting process
leads one to believe that the differences between theory and practice can be attributed to
deficiencies in the theory itself. This was also outlined by Pinches (1982:16), emphasising
the theory of the capital budgeting process and its practice as myopic, by stating that:

... the main failure of academicians is due to focusing too much of their attention
on the selection phase to the exclusion of the identification, development, and
control phases. Very little attention has been given to the interface between
strategic planning and capital budgeting... Business executives, on the other
hand, have been equally myopic concerning the capital budgeting process.
While many of them are very aware of the different phases, the interrelationships
between phases are often not dealt with effectively...

Therefore, the results obtained from the respondents are in line with the above statements
cited by Mukherjee and Handerson, as well as by Pinches. The results reveal that 56
percent of the respondents use the financial evaluation phase of the capital budgeting
process (refer to Appendix C, Table C5), and only 14 percent of the respondents use the
strategic evaluation phase in their investment decision. The study also reveals that there are
inconsistencies between the pertinent theory and the actual practice of capital budgeting.

Regarding the origin of investment opportunities, the top management of more than 93
percent of the respondents initiate the firm's investment opportunities.

The general trend for stratification by size of manufacturer and the application of the four
phases of the investment process revealed that the larger the manufacturer, the greater the
tendency to use strategic planning. On the other hand, stratification by type of manufacturer
did not reveal any particular trend in the use of certain investment phases.

A major reason for not using strategic aspects in the investment decision-making seemed to
be the lack of sufficient investment funds or the firm being "too small" to consider some of
the strategic aspects and to use some financial techniques in the investment decision making.

In terms of awareness of the analytic hierarchy process method, very few South African
manufacturers (namely four percent of the respondents) are aware of the AHP method, and
the method is not even applied in their firms.
7.3 RECOMMENDATIONS

This study examined the responses received mainly from large manufacturing companies concerning their use of strategic aspects in investment decision making. An opportunity for further research into this field could be a study embracing other sectors of the economy in order to evaluate their strategies in this regard also.

Due to the relative nature of the comparisons, it was not possible to establish the performance of the firms in both the short-term and the long-run of their activities as manufacturers. This is especially valid with regard to the small manufacturing firms, where the data was far too limited. The performance comparison can be used in order to understand why one company has been more successful than another, especially when firms have adopted exactly the same strategy. It is recommended that an in-depth study be undertaken in this regard.
BIBLIOGRAPHY

SOURCES QUOTED


Saaty, T.L. 1990. An explosion of the AHP in reply to the paper: remarks on the Analytic


SOURCES CONSULTED


### Appendix A

#### CAPITAL EXPENDITURE OF MANUFACTURING FIRMS 1982-1992

<table>
<thead>
<tr>
<th>YEAR</th>
<th>AMOUNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>4,945,030</td>
</tr>
<tr>
<td>1983</td>
<td>5,386,331</td>
</tr>
<tr>
<td>1984</td>
<td>4,929,577</td>
</tr>
<tr>
<td>1985</td>
<td>4,152,316</td>
</tr>
<tr>
<td>1986</td>
<td>3,473,674</td>
</tr>
<tr>
<td>1987</td>
<td>4,211,455</td>
</tr>
<tr>
<td>1988</td>
<td>5,708,400</td>
</tr>
<tr>
<td>1989</td>
<td>10,970,746</td>
</tr>
<tr>
<td>1990</td>
<td>13,927,314</td>
</tr>
<tr>
<td>1991</td>
<td>12,436,996</td>
</tr>
<tr>
<td>1992</td>
<td>12,309,337</td>
</tr>
</tbody>
</table>
Appendix B

Letters accompanying the questionnaires to the financial managers

Telephone enquiries: (011) 640-5587

P.O. Box 93690
Yeoville
2143

Date: 07 October 1996

Dear Sir/Madam,

STRATEGIC ASPECTS IN INVESTMENT DECISION-MAKING

I am undertaking a research study as part of the Degree of Masters in Business Management at the University of South Africa. The topic is "Strategic Aspects in investment decision-making" and the objective of the enclosed questionnaire is to obtain the views of Financial Managers of manufacturing firms in the Gauteng region.

Your company has been selected from a list of Bureau of Market Research (BMR) under Standard Industrial Classification (SIC).

I would be grateful if you would complete the questionnaire and return it in the reply paid envelope as soon as possible. The questionnaire has been drawn up in such a way that it could be answered within 15 minutes.

Due to limited resources a fairly small sample was selected to receive this questionnaire. Thus, your response is very important to the success of the survey. All information will be treated in the strictest confidence and the respondent's name (optional information) will not be revealed.

I should like to thank you in anticipation for your co-operation.

Yours faithfully,

D. Matundu
SURVEY QUESTIONNAIRE

STRATEGIC ASPECTS IN INVESTMENT DECISION-MAKING BY MANUFACTURERS IN THE GAUTENG REGION OF SOUTH AFRICA

(Please note that all questions should be answered by checking the appropriate block, e.g. [✓] and/or by inserting a single word or phrase where necessary).

1) Name of the firm ................................................................. 1-3

2) Name of the informant (optional) .................................

3) Position of the informant (Title description) ...........

4) Nature of business or type of activity:

<table>
<thead>
<tr>
<th>Nature of Business or Type of Activity</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food, beverages and tobacco</td>
<td>1</td>
</tr>
<tr>
<td>Textiles, clothing and leather</td>
<td>2</td>
</tr>
<tr>
<td>Wood and cork products</td>
<td>3</td>
</tr>
<tr>
<td>Paper, printing and publishing</td>
<td>4</td>
</tr>
<tr>
<td>Industrial chemicals, petroleum, coal and plastics</td>
<td>5</td>
</tr>
<tr>
<td>Pottery, glass and other nonmetallic products</td>
<td>6</td>
</tr>
<tr>
<td>Iron, steel and nonferrous metal</td>
<td>7</td>
</tr>
<tr>
<td>Machinery, electrical transport and scientific equipment</td>
<td>8</td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>9</td>
</tr>
</tbody>
</table>

5) Approximate number of employees:

<table>
<thead>
<tr>
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<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
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<td>01</td>
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<tr>
<td>5 - 9</td>
<td>02</td>
</tr>
<tr>
<td>10 - 19</td>
<td>03</td>
</tr>
<tr>
<td>20 - 49</td>
<td>04</td>
</tr>
<tr>
<td>50 - 99</td>
<td>05</td>
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<tr>
<td>100 - 199</td>
<td>06</td>
</tr>
<tr>
<td>200 - 299</td>
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</tr>
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<td>300 - 399</td>
<td>08</td>
</tr>
<tr>
<td>400 - 499</td>
<td>09</td>
</tr>
<tr>
<td>500 - 999</td>
<td>10</td>
</tr>
<tr>
<td>1000 and plus</td>
<td>11</td>
</tr>
</tbody>
</table>
6) What is your approximate annual turnover (sales)?

<table>
<thead>
<tr>
<th>Range</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than R30 000</td>
<td>1</td>
</tr>
<tr>
<td>R30 001 - R100 000</td>
<td>2</td>
</tr>
<tr>
<td>R100 001 - R500 000</td>
<td>3</td>
</tr>
<tr>
<td>R500 001 - R1 000 000</td>
<td>4</td>
</tr>
<tr>
<td>R1 000 001 - R5 000 000</td>
<td>5</td>
</tr>
<tr>
<td>R5 000 001 and plus</td>
<td>6</td>
</tr>
</tbody>
</table>

7) What is your approximate value of your total assets?

<table>
<thead>
<tr>
<th>Range</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than R30 000</td>
<td>1</td>
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<tr>
<td>R30 001 - R100 000</td>
<td>2</td>
</tr>
<tr>
<td>R100 001 - R500 000</td>
<td>3</td>
</tr>
<tr>
<td>R500 001 - R1 000 000</td>
<td>4</td>
</tr>
<tr>
<td>R1 000 001 - R5 000 000</td>
<td>5</td>
</tr>
<tr>
<td>R5 000 001 and plus</td>
<td>6</td>
</tr>
</tbody>
</table>

8) What is the most important step of your capital budgeting process? (Please tick one only)

<table>
<thead>
<tr>
<th>Step</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification and generation of idea</td>
<td>1</td>
</tr>
<tr>
<td>Project strategic evaluation</td>
<td>2</td>
</tr>
<tr>
<td>Project financial evaluation</td>
<td>3</td>
</tr>
<tr>
<td>Project implementation</td>
<td>4</td>
</tr>
<tr>
<td>Post-implementation audit and control</td>
<td>5</td>
</tr>
<tr>
<td>None</td>
<td>6</td>
</tr>
</tbody>
</table>

9) If your answer to question 8 is None, please state the reason for this: .................................

.................................................................
10) Who identifies investment opportunities in your firm?

<table>
<thead>
<tr>
<th>Option</th>
<th>Count</th>
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</thead>
<tbody>
<tr>
<td>Top management</td>
<td>1</td>
</tr>
<tr>
<td>Middle management</td>
<td>2</td>
</tr>
<tr>
<td>Lower management</td>
<td>3</td>
</tr>
<tr>
<td>Others</td>
<td>4</td>
</tr>
</tbody>
</table>

11) What percentage of time do you spend on evaluating investment ideas?

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 10%</td>
<td>1</td>
</tr>
<tr>
<td>10 - 19%</td>
<td>2</td>
</tr>
<tr>
<td>20 - 39%</td>
<td>3</td>
</tr>
<tr>
<td>40 - 59%</td>
<td>4</td>
</tr>
<tr>
<td>60% and plus</td>
<td>5</td>
</tr>
</tbody>
</table>

12) What percentage of time do you spend to evaluate acceptable investment proposals?

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 10%</td>
<td>1</td>
</tr>
<tr>
<td>10 - 19%</td>
<td>2</td>
</tr>
<tr>
<td>20 - 39%</td>
<td>3</td>
</tr>
<tr>
<td>40 - 59%</td>
<td>4</td>
</tr>
<tr>
<td>60% and plus</td>
<td>5</td>
</tr>
</tbody>
</table>

13) Which of the following techniques do you use in order to evaluate projects? (You may tick more than one block)

<table>
<thead>
<tr>
<th>Technique</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>The payback period and discounted payback period</td>
<td>1</td>
</tr>
<tr>
<td>Average rate of return (ARR)</td>
<td>1</td>
</tr>
<tr>
<td>Net present value (NPV)</td>
<td>1</td>
</tr>
<tr>
<td>Internal rate of return (IRR)</td>
<td>1</td>
</tr>
<tr>
<td>The profitability index (PI)</td>
<td>1</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
</tr>
</tbody>
</table>
14) If your answer to question 13 is None, please state the reason for this: ..........................................................
................................................................................................................

15) Does your firm calculate the weighted average cost of capital (WACC)?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
</tr>
</tbody>
</table>

16) If your answer to question 15 is No, please state the reason for this:

(Tick one block only)

<table>
<thead>
<tr>
<th>Reason</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>1</td>
</tr>
<tr>
<td>Not familiar</td>
<td>2</td>
</tr>
<tr>
<td>Have no time</td>
<td>3</td>
</tr>
<tr>
<td>Do not need it</td>
<td>4</td>
</tr>
<tr>
<td>Other reasons (please specify)</td>
<td>5</td>
</tr>
<tr>
<td>R5 000 001 and-plus</td>
<td>6</td>
</tr>
</tbody>
</table>

17) How do you judge the techniques of capital budgeting?

<table>
<thead>
<tr>
<th>Judgement</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>1</td>
</tr>
<tr>
<td>Sophisticated</td>
<td>2</td>
</tr>
<tr>
<td>Purely academic</td>
<td>3</td>
</tr>
<tr>
<td>Difficult</td>
<td>4</td>
</tr>
<tr>
<td>Very difficult</td>
<td>5</td>
</tr>
<tr>
<td>Unpracticable</td>
<td>6</td>
</tr>
</tbody>
</table>

18) Do you take quantifiable as well as nonquantifiable factors into account when making Investment decisions?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
</tr>
</tbody>
</table>
19) How often are nonquantifiable factors taken into consideration in your investment process?

- Always 1
- Sometimes 2
- Never 3

20) If your answer to question 19 is Never, please state the reason for this:

21) Does your firm incorporate other nonfinancial factors in the investment decision-making process such as the role of organizational structure and behaviour?

- Yes 1
- No 2

22) How often do you incorporate the role of organizational structure and behaviour in investment process?

- Always 1
- Sometimes 2
- Never 3

23) If your answer to question 22 is Never, please state the reason for this:

24) Are you aware of the method called the analytic hierarchy process (AHP)?

- Yes 1
- No 2

If Yes, please answer questions 25 to 33
If No, please go to question 34.
25) Does your firm apply the AHP method?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
</tr>
</tbody>
</table>

26) If your answer to question 25 is Yes, which approach do you use in order to apply AHP method?

<table>
<thead>
<tr>
<th>Approach</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission, Objective, Strategies (MOS) approaches</td>
<td>1</td>
</tr>
<tr>
<td>Others (please specify)</td>
<td>2</td>
</tr>
</tbody>
</table>

27) How do you judge approaches of the AHP method?

<table>
<thead>
<tr>
<th>Difficulty</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>1</td>
</tr>
<tr>
<td>Sophisticated</td>
<td>2</td>
</tr>
<tr>
<td>Purely academic</td>
<td>3</td>
</tr>
<tr>
<td>Difficult</td>
<td>4</td>
</tr>
<tr>
<td>Very difficult</td>
<td>5</td>
</tr>
<tr>
<td>Umpracticable</td>
<td>6</td>
</tr>
</tbody>
</table>

28) Does the AHP method help in the capital investment process?

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>1</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
</tr>
</tbody>
</table>

29) If your answer to question 28 is No, please state the reason for this: ......................
30) Which step of the capital budgeting process requires use of the AHP method?  
**(Tick one block only)**

<table>
<thead>
<tr>
<th>Identification and generation of idea</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project strategic evaluation</td>
<td>2</td>
</tr>
<tr>
<td>Project financial evaluation</td>
<td>3</td>
</tr>
<tr>
<td>Project implementation</td>
<td>4</td>
</tr>
<tr>
<td>Post-implementation audit and control</td>
<td>5</td>
</tr>
<tr>
<td>None</td>
<td>6</td>
</tr>
</tbody>
</table>

31) If your answer to question 30 is None, please state the reason for this: ...............................  
...........................................................................................................................

32) Can the AHP method solve the problem of linking capital budgeting to strategic aspects?  
**(Please mark the appropriate answer)**

<table>
<thead>
<tr>
<th>Always true</th>
<th>Nearly always true</th>
<th>Usually true</th>
<th>sometimes true</th>
<th>rarely true</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

33) How does the AHP method help in investment decision-making?  
**(Please mark the appropriate answer)**

<table>
<thead>
<tr>
<th>Extremely good</th>
<th>Fairly good</th>
<th>Good</th>
<th>Poor</th>
<th>Fairly Poor</th>
<th>Extremely poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

34) Any other comments or remarks concerning the strategic aspects in investment decision-making:  
...........................................................................................................................
...........................................................................................................................

i05
Appendix C

FREQUENCIES ON ALL QUESTIONNAIRE VARIABLES

**TABLE C1: NATURE OF INDUSTRY**

<table>
<thead>
<tr>
<th>Industry</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOOD</td>
<td>5</td>
<td>3.3</td>
</tr>
<tr>
<td>TEXTILES</td>
<td>4</td>
<td>2.7</td>
</tr>
<tr>
<td>WOOD</td>
<td>8</td>
<td>5.3</td>
</tr>
<tr>
<td>PAPER</td>
<td>15</td>
<td>10.0</td>
</tr>
<tr>
<td>CHEMICALS</td>
<td>29</td>
<td>19.3</td>
</tr>
<tr>
<td>POTTERY</td>
<td>6</td>
<td>4.0</td>
</tr>
<tr>
<td>IRON</td>
<td>16</td>
<td>10.7</td>
</tr>
<tr>
<td>MACHINERY</td>
<td>44</td>
<td>29.3</td>
</tr>
<tr>
<td>OTHER</td>
<td>23</td>
<td>15.3</td>
</tr>
</tbody>
</table>

**TABLE C2: NUMBER OF EMPLOYEES**

<table>
<thead>
<tr>
<th>Number of Employees</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td>6</td>
<td>4.0</td>
</tr>
<tr>
<td>5-9</td>
<td>5</td>
<td>3.3</td>
</tr>
<tr>
<td>10-19</td>
<td>22</td>
<td>14.6</td>
</tr>
<tr>
<td>20-49</td>
<td>34</td>
<td>22.5</td>
</tr>
<tr>
<td>50-99</td>
<td>22</td>
<td>14.6</td>
</tr>
<tr>
<td>100-199</td>
<td>20</td>
<td>13.2</td>
</tr>
<tr>
<td>200-299</td>
<td>19</td>
<td>12.6</td>
</tr>
<tr>
<td>300-399</td>
<td>6</td>
<td>4.0</td>
</tr>
<tr>
<td>400-499</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>500-599</td>
<td>6</td>
<td>5.3</td>
</tr>
<tr>
<td>1000+</td>
<td>6</td>
<td>4.0</td>
</tr>
</tbody>
</table>

**TABLE C3: ANNUAL TURNOVER**

<table>
<thead>
<tr>
<th>Turnover</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;R30000</td>
<td>1</td>
<td>0.7</td>
</tr>
<tr>
<td>30000-100000</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>1000001-500000</td>
<td>7</td>
<td>4.6</td>
</tr>
<tr>
<td>5000001-1000000</td>
<td>21</td>
<td>13.9</td>
</tr>
<tr>
<td>10000001-5000000</td>
<td>41</td>
<td>27.2</td>
</tr>
<tr>
<td>50000001+</td>
<td>79</td>
<td>52.3</td>
</tr>
</tbody>
</table>
### TABLE C4: TOTAL ASSETS

<table>
<thead>
<tr>
<th>Q7</th>
<th>FREQUENCY</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;R30000</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>30000-100000</td>
<td>8</td>
<td>5.3</td>
</tr>
<tr>
<td>100001-500000</td>
<td>34</td>
<td>22.7</td>
</tr>
<tr>
<td>500001-1000000</td>
<td>17</td>
<td>11.3</td>
</tr>
<tr>
<td>1000001-5000000</td>
<td>32</td>
<td>21.3</td>
</tr>
<tr>
<td>5000001+</td>
<td>57</td>
<td>38.0</td>
</tr>
</tbody>
</table>

### TABLE C5: CAPITAL BUDGETING PROCESS

<table>
<thead>
<tr>
<th>Q8</th>
<th>FREQUENCY</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDENTIF</td>
<td>35</td>
<td>23.5</td>
</tr>
<tr>
<td>STRATEGY</td>
<td>22</td>
<td>14.8</td>
</tr>
<tr>
<td>FINANCIAL</td>
<td>84</td>
<td>56.4</td>
</tr>
<tr>
<td>POST IMPL</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>NONE</td>
<td>6</td>
<td>4.0</td>
</tr>
</tbody>
</table>

### TABLE C6: INVESTMENT OPPORTUNITIES

<table>
<thead>
<tr>
<th>Q10</th>
<th>FREQUENCY</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOP</td>
<td>143</td>
<td>95.3</td>
</tr>
<tr>
<td>MIDDLE</td>
<td>6</td>
<td>4.0</td>
</tr>
<tr>
<td>LOWER</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>OTHER</td>
<td>1</td>
<td>0.7</td>
</tr>
</tbody>
</table>

### TABLE C7: TIME SPENT ON EVALUATION

<table>
<thead>
<tr>
<th>Q11</th>
<th>FREQUENCY</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10%</td>
<td>89</td>
<td>59.3</td>
</tr>
<tr>
<td>10-19%</td>
<td>33</td>
<td>22.0</td>
</tr>
<tr>
<td>20-39%</td>
<td>18</td>
<td>12.0</td>
</tr>
<tr>
<td>40-59%</td>
<td>8</td>
<td>5.3</td>
</tr>
<tr>
<td>60%</td>
<td>2</td>
<td>1.3</td>
</tr>
</tbody>
</table>

### TABLE C8: TIME SPENT ON INVESTMENT PROPOSALS

<table>
<thead>
<tr>
<th>Q12</th>
<th>FREQUENCY</th>
<th>PERCENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10%</td>
<td>109</td>
<td>73.2</td>
</tr>
<tr>
<td>10-19%</td>
<td>25</td>
<td>16.8</td>
</tr>
<tr>
<td>20-39%</td>
<td>8</td>
<td>5.4</td>
</tr>
<tr>
<td>40-59%</td>
<td>5</td>
<td>3.4</td>
</tr>
<tr>
<td>60%</td>
<td>2</td>
<td>1.3</td>
</tr>
</tbody>
</table>
### TABLE C9: USE OF PAYBACK TECHNIQUE

<table>
<thead>
<tr>
<th>Q131</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>69</td>
<td>46.0</td>
</tr>
<tr>
<td>NO</td>
<td>81</td>
<td>54.0</td>
</tr>
</tbody>
</table>

### TABLE C10: USE OF ARR TECHNIQUE

<table>
<thead>
<tr>
<th>Q132</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>50</td>
<td>33.3</td>
</tr>
<tr>
<td>NO</td>
<td>100</td>
<td>66.7</td>
</tr>
</tbody>
</table>

### TABLE C11: USE OF NPV TECHNIQUE

<table>
<thead>
<tr>
<th>Q133</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>57</td>
<td>38.0</td>
</tr>
<tr>
<td>NO</td>
<td>93</td>
<td>62.0</td>
</tr>
</tbody>
</table>

### TABLE C12: USE OF IRR TECHNIQUE

<table>
<thead>
<tr>
<th>Q134</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>42</td>
<td>28.0</td>
</tr>
<tr>
<td>NO</td>
<td>108</td>
<td>72.0</td>
</tr>
</tbody>
</table>

### TABLE C13: USE OF PI TECHNIQUE

<table>
<thead>
<tr>
<th>Q135</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>43</td>
<td>28.7</td>
</tr>
<tr>
<td>NO</td>
<td>107</td>
<td>71.3</td>
</tr>
</tbody>
</table>

### TABLE C14: USE OF NO TECHNIQUE

<table>
<thead>
<tr>
<th>Q136</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>7</td>
<td>4.7</td>
</tr>
<tr>
<td>NO</td>
<td>143</td>
<td>95.3</td>
</tr>
</tbody>
</table>

### TABLE C15: USE WACC

<table>
<thead>
<tr>
<th>Q15</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>64</td>
<td>42.7</td>
</tr>
<tr>
<td>NO</td>
<td>86</td>
<td>57.3</td>
</tr>
</tbody>
</table>
### Table C16: Reasons for WACC

<table>
<thead>
<tr>
<th>Q16</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown</td>
<td>17</td>
<td>19.8</td>
</tr>
<tr>
<td>Not Familiar</td>
<td>22</td>
<td>25.6</td>
</tr>
<tr>
<td>No Time</td>
<td>5</td>
<td>5.8</td>
</tr>
<tr>
<td>Not Need</td>
<td>41</td>
<td>47.7</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>1.2</td>
</tr>
</tbody>
</table>

### Table C17: Opinions for Techniques

<table>
<thead>
<tr>
<th>Q17</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>48</td>
<td>32.7</td>
</tr>
<tr>
<td>Sophisticated</td>
<td>28</td>
<td>19.0</td>
</tr>
<tr>
<td>Purely Acedem</td>
<td>29</td>
<td>19.7</td>
</tr>
<tr>
<td>Difficult</td>
<td>16</td>
<td>10.9</td>
</tr>
<tr>
<td>Very Diff.</td>
<td>8</td>
<td>5.4</td>
</tr>
<tr>
<td>Unpracticable</td>
<td>18</td>
<td>12.2</td>
</tr>
</tbody>
</table>

### Table C18: Use of Nonquantifiable Factors

<table>
<thead>
<tr>
<th>Q18</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>137</td>
<td>91.9</td>
</tr>
<tr>
<td>No</td>
<td>12</td>
<td>8.1</td>
</tr>
</tbody>
</table>

### Table C19: Frequency of Use of Nonquantifiable

<table>
<thead>
<tr>
<th>Q19</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always</td>
<td>68</td>
<td>46.9</td>
</tr>
<tr>
<td>Sometimes</td>
<td>71</td>
<td>49.0</td>
</tr>
<tr>
<td>Never</td>
<td>6</td>
<td>4.1</td>
</tr>
</tbody>
</table>

### Table C20: Use of Nonfinancial Factors

<table>
<thead>
<tr>
<th>Q21</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>129</td>
<td>87.2</td>
</tr>
<tr>
<td>No</td>
<td>19</td>
<td>12.8</td>
</tr>
</tbody>
</table>

### Table C21: Frequency of Use of Organizational Structure

<table>
<thead>
<tr>
<th>Q22</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Always</td>
<td>25</td>
<td>17.0</td>
</tr>
<tr>
<td>Sometimes</td>
<td>108</td>
<td>73.5</td>
</tr>
<tr>
<td>Never</td>
<td>14</td>
<td>9.5</td>
</tr>
</tbody>
</table>
### TABLE C22: AWARENESS OF THE AHP

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>6</td>
<td>4.0</td>
</tr>
<tr>
<td>No</td>
<td>143</td>
<td>96.0</td>
</tr>
</tbody>
</table>

### TABLE C23: APPLICATION OF THE AHP

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>No</td>
<td>150</td>
<td>100.0</td>
</tr>
</tbody>
</table>

### TABLE C24: OPINIONS FOR THE AHP

<table>
<thead>
<tr>
<th>Opinion</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easy</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Sophisticated</td>
<td>1</td>
<td>33.3</td>
</tr>
<tr>
<td>Purely Academ</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Difficult</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Very Diff.</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Unreal</td>
<td>2</td>
<td>66.7</td>
</tr>
</tbody>
</table>

### TABLE C25: USE OF THE AHP IN INVESTMENT

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>2</td>
<td>50.0</td>
</tr>
<tr>
<td>No</td>
<td>2</td>
<td>50.0</td>
</tr>
</tbody>
</table>

### TABLE C26: USE OF AHP IN CAPITAL BUDGETING PROCESS

<table>
<thead>
<tr>
<th>Category</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identify</td>
<td>1</td>
<td>25.0</td>
</tr>
<tr>
<td>Strategy</td>
<td>2</td>
<td>50.0</td>
</tr>
<tr>
<td>Financial</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>Post Impl</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>None</td>
<td>1</td>
<td>25.0</td>
</tr>
</tbody>
</table>
### TABLE C27: LINKING CAPITAL BUDGETING TO STRATEGY

<table>
<thead>
<tr>
<th>Q32</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALWAYS TRUE</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>NEARLY ALWAYS</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>USUALLY TRUE</td>
<td>2</td>
<td>50.0</td>
</tr>
<tr>
<td>SOMETIMES</td>
<td>1</td>
<td>25.0</td>
</tr>
<tr>
<td>RARELY TRUE</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>NEVER</td>
<td>1</td>
<td>25.0</td>
</tr>
</tbody>
</table>

### TABLE C28: OPINION ON DECISION-MAKING

<table>
<thead>
<tr>
<th>Q33</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXTREMELY GOOD</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>FAIRLY GOOD</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>GOOD</td>
<td>1</td>
<td>50.0</td>
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<tr>
<td>POOR</td>
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<tr>
<td>FAIRLY POOR</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>EXTREMELY POOR</td>
<td>0</td>
<td>0.0</td>
</tr>
</tbody>
</table>
ANNEXURE A

AXIOMATIC FOUNDATION OF THE ANALYTIC HIERARCHY PROCESS*

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This paper contains an axiomatic treatment of the Analytic Hierarchy Process (AHP). The set of axioms corresponding to hierarchic structures are a special case of axioms for priority setting in systems with feedback which allow for a wide class of dependencies. The axioms highlight: (1) the reciprocal property that is basic in making paired comparisons; (2) homogeneity that is characteristic of people's ability for making comparisons among things that are not too dissimilar with respect to a common property and, hence, the need for arranging them within an order preserving hierarchy; (3) dependence of a lower level on the adjacent higher level; (4) the idea that an outcome can only reflect expectations when the latter are well represented in the hierarchy. The AHP neither assumes transitivity (or the stronger condition of consistency) nor does it include strong assumptions of the usual notions of rationality. A number of facts are derived from these axioms providing an operational basis for the AHP.

1. Introduction

The basic problem of decision making is to choose a best one in a set of competing alternatives that are evaluated under conflicting criteria. The Analytic Hierarchy Process (AHP) provides us with a comprehensive framework for solving such problems. It enables us to cope with the intuitive, the rational, and the irrational, all at the same time, when we make multicriteria and multiactor decisions. We can use the AHP to integrate our perceptions and purposes into an overall synthesis. The AHP does not require that judgments be consistent or even transitive. The degree of consistency (or inconsistency) of the judgments is revealed at the end of the AHP process.

Most of us have difficulty examining even a few ideas at a time. We need instead to organize our problems in complex structures which allow us to think about them one or two at a time. We need simplicity and complexity. We need an approach that is conceptually simple so that we can use it easily. And at the same time, we need an approach that is robust enough to handle real world decisions and complexities.

The Analytic Hierarchy Process is such a problem-solving framework. It is a systematic procedure for representing the elements of any problem. It organizes the basic rationality by breaking down a problem into its smaller constituent parts and then calls for only simple pairwise comparison judgments to develop priorities in each hierarchy.

There are three principles which one can recognize in problem solving. They are the principles of decomposition, comparative judgments, and synthesis of priorities.

The decomposition principle calls for structuring the hierarchy to capture the basic elements of the problem. An effective way to do this is first to work downward from the focus in the top level to criteria bearing on the focus in the second level, followed by subcriteria in the third level, and so on, from the more general (and sometimes uncertain) to the more particular and definite. One can then start at the bottom, identifying alternatives for that level and attributes under which they should be

*Accepted by Ambar G. Rao; received October 1, 1984. This paper has been with the author 6 months for 1 revision.
compared which fall in the next level up. Then one finds an intermediate set of higher criteria that can both be decomposed into these attributes and are themselves decompositions of the higher level criteria or subcriteria identified in the downward process. In this way, one can link the focus of the hierarchy to its bottom level in a sequence of appropriate intermediate levels. The levels of a decomposition are an essential part of measurement, and, hence, adjacent ones should generally not be too disparate, that is they do not differ by more than a "qualitative" order of magnitude. In general, the bottom level of the hierarchy contains the resources to be allocated, or the alternatives from which the choice is to be made. (See Figure 1.)

The principle of comparative judgments calls for setting up a matrix to carry out pairwise comparisons of the relative importance of the elements in the second level with respect to the overall objective (or focus) of the first level. In the case where no scale of measurement exists, this is a judgment made by the individual or group solving the problem. The scale for entering judgments is given in Table 1. Additional comparison matrices are used to compare the elements of the third level with respect to the appropriate parents in the second, and so on down the hierarchy. The process could be started at the bottom level and move upward. An entry of each matrix belongs to a fundamental scale employed in the comparisons. These entries are used to generate a derived ratio scale. The next step deals with the composition of the derived ratio scales.

The synthesis of priorities principle is now applied. Priorities are synthesized from the second level down by multiplying local priorities by the priority of the corresponding criterion in the level above, and adding them for each element in a level according to the criteria it affects. (The second level elements are each multiplied by unity, the weight of the single top level goal.) This gives the composite or global priority of that element which is then used to weight the local priorities of elements in the level below compared by it as criterion, and so on to the bottom level.

The AHP contains an intrinsic measure of inconsistency for each matrix and for the whole hierarchy. Knowledge of inconsistency enables one to determine those judgments which need reassessment.

When a group uses the AHP, their judgments can be combined after discussion by applying the geometric mean to the judgments which derives from the requirement
<table>
<thead>
<tr>
<th>Intensity of Relative Importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the objective.</td>
</tr>
<tr>
<td>3</td>
<td>Moderate importance of one over another</td>
<td>Experience and judgment slightly favor one activity over another.</td>
</tr>
<tr>
<td>5</td>
<td>Essential or strong importance</td>
<td>Experience and judgment strongly favor one activity over another.</td>
</tr>
<tr>
<td>7</td>
<td>Demonstrated importance</td>
<td>An activity is strongly favored and its dominance is demonstrated in practice.</td>
</tr>
<tr>
<td>9</td>
<td>Extreme importance</td>
<td>The evidence favoring one activity over another is of the highest possible order of affirmation.</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Intermediate values between the two adjacent judgments</td>
<td>When compromise is needed.</td>
</tr>
</tbody>
</table>

Reciprocals of above non-zero numbers:
- If an activity has one of the above numbers assigned to it when compared with a second activity, then the second activity has the reciprocal value when compared to the first.

Rationals:
- Ratios arising from the scale
- If consistency were to be forced by obtaining \( n \) numerical values to span the matrix.

Remark: When only two objects are compared it may be desirable to expand the interval \( 1, 2 \) (from equal to slight importance) by inserting the values, \( 1.1, 1.2, \ldots, 1.9 \), starting with 1.1 as very slight, 1.2 as slight, 1.3 as moderate, etc.

That the collective judgment itself must satisfy the reciprocal property (Aczel and Saaty 1983).

The AHP can be applied to set priorities on the criteria and subcriteria of the hierarchy. The alternatives may be evaluated by paired comparisons (relative measurement). When there are many alternatives, and neither their number nor their kind affect the importance of the criteria, they can be absolutely measured or scored on each criterion according to merit or degree to which they meet the standards (see §4).

Many decision problems involve dependence of criteria on alternatives and of
higher order criteria on lower order ones; also alternatives may depend on other alternatives. A particularly useful generalization of the theory to deal with such dependence situations has been formalized within a network system with feedback of which a hierarchy is a special case.

The purpose of this paper is to state the axioms on which the AHP is based and to show how the theory of the AHP is derived from these axioms. For a more basic introduction to the AHP and its many applications, the reader is referred to Saaty (1980).

2. Axioms for Deriving a Scale from Fundamental Measurement and for Hierarchic Composition

Let \( \mathbb{A} \) be a finite set of \( n \) elements called alternatives. Let \( \mathcal{E} \) be a set of properties or attributes with respect to which elements in \( \mathbb{A} \) are compared. Philosophers distinguish between properties and attributes. A property is a feature that an object or individual possesses even if we are ignorant of this fact. On the other hand an attribute is a feature we assign to some object: it is a concept. Here we assume that properties and attributes are interchangeable and generally refer to them as criteria. A criterion is a primitive.

When two objects or elements in \( \mathbb{A} \) are compared according to a criterion in \( \mathcal{E} \), we say that we are performing binary comparisons. Let \( >_C \) be a binary relation on \( \mathbb{A} \) representing "more preferred than" with respect to a criterion in \( \mathcal{E} \). Let \( \sim_C \) be the binary relation "indifferent to" with respect to a criterion \( C \) in \( \mathcal{E} \). Hence, given two elements, \( A_i, A_j \in \mathbb{A} \), either \( A_i >_C A_j \) or \( A_j >_C A_i \) or \( A_i \sim_C A_j \) for all \( C \in \mathcal{E} \). We use \( A_i \geq_C A_j \) to indicate more preferred or indifferent. A given family of binary relations \( >_C \) with respect to a criterion \( C \) in \( \mathcal{E} \) is a primitive.

Let \( \mathcal{F} \) be the set of mappings from \( \mathbb{A} \times \mathbb{A} \) to \( \mathbb{R}^+ \) (the set of positive reals). Let \( f : \mathcal{E} \to \mathcal{F} \). Let \( P_C \in f(C) \) for \( C \in \mathcal{E} \). \( P_C \) assigns a positive real number to every pair \( (A_i, A_j) \in \mathbb{A} \times \mathbb{A} \). Let \( P_C(A_i, A_j) \equiv a_{ij} \in \mathbb{R}^+ \), \( A_i, A_j \in \mathbb{A} \). For each \( C \in \mathcal{E} \), the triple \( (\mathbb{A} \times \mathbb{A}, \mathbb{R}^+, P_C) \) is a fundamental or primitive scale. A fundamental scale is a mapping of objects to a numerical system.

**Definition.** For all \( A_i, A_j \in \mathbb{A} \) and \( C \in \mathcal{E} \)

\[
A_i >_C A_j \quad \text{if and only if} \quad P_C(A_i, A_j) > 1, \\
A_i \sim_C A_j \quad \text{if and only if} \quad P_C(A_i, A_j) = 1.
\]

If \( A_i >_C A_j \) we say that \( A_i \) dominates \( A_j \) with respect to \( C \in \mathcal{E} \). Thus \( P_C \) represents the intensity or strength of preference for one alternative over another.

**Axiom 1 (Reciprocal).** For all \( A_i, A_j \in \mathbb{A} \) and \( C \in \mathcal{E} \)

\[
P_C(A_j, A_i) = 1/P_C(A_i, A_j).
\]

Whenever we make paired comparisons we need to consider both members of the pair to judge the relative value. If one stone is judged to be five times heavier than another, then the other is automatically one fifth as heavy as the first because it participated in making the first judgment. The comparison matrices that we consider are formed by making paired reciprocal comparisons. It is this simple, but powerful means of resolving multicriteria problems that is the basis of the AHP.

Let \( A = (a_{ij}) \equiv (P_C(A_i, A_j)) \) be the set of paired comparisons of the alternatives with respect to a criterion \( C \in \mathcal{E} \). By Axiom 1, \( A \) is a positive reciprocal matrix. The object is to obtain a scale of relative dominance (or rank order) of the alternatives from the paired comparisons given in \( A \).

There is a natural way to derive the relative dominance of a set of alternatives from
Homogeneity is essential for comparing similar things, as the mind tends to make large errors in comparing widely disparate elements. For example we cannot compare a grain of sand with an orange according to size. When the disparity is great, the elements are placed in separate clusters of comparable size giving rise to the idea of levels and their decomposition. This axiom is closely related to the well-known Archimedean property.

The notions of fundamental and derived scales can be extended to $x \in L_k$, $x^{-} \subseteq L_{k+1}$ replacing $c$ and $\mathfrak{A}$ respectively. The derived scale resulting from comparing the elements in $x^{-}$ with respect to $x$ is called a local derived scale or local priorities. Here no irrelevant alternative is included in the comparisons and such alternatives are assumed to receive the value of zero in the derived scale.

Given $L_k$, $L_{k+1} \subseteq \mathfrak{A}$, let us denote the local derived scale for $y \in x^{-}$ and $x \in L_k$ by $\psi_k+1(y/x)$. $k = 2, 3, \ldots, h-1$. Without loss of generality we may assume that $\sum_{y \in x} \psi_k+1(y/x) = 1$. Consider the matrix $\psi_k(L_k/L_{k-1})$ whose columns are local derived scales of elements in $L_k$ with respect to elements in $L_{k-1}$.

Definition. A set $\mathfrak{A}$ is said to be outer dependent on a set $\mathfrak{U}$ if a fundamental scale can be defined on $\mathfrak{A}$ with respect to every $c \in \mathfrak{U}$.

Decomposition implies containment of the small elements by the large clusters or levels. In turn, this means that the smaller elements depend on the outer parent elements to which they belong, which themselves fall in a large cluster of the hierarchy. The process of relating elements (e.g., alternatives) in one level of the hierarchy according to the elements of the next higher level (e.g., criteria) expresses the dependence of the lower elements on the higher so that comparisons can be made between them. The steps are repeated upward in the hierarchy through each pair of adjacent levels to the top element, the focus or goal.

The elements in a level may depend on one another with respect to a property in another level. Input-output dependence of industries is an example of the idea of inner dependence. This may be formalized as follows:

Definition. Let $\mathfrak{A}$ be outer dependent on $\mathfrak{U}$. The elements in $\mathfrak{A}$ are said to be inner dependent with respect to $C \in \mathfrak{U}$ if for some $A \in \mathfrak{A}$, $\mathfrak{A}$ is outer dependent on $A$.

Axiom 3. Let $\mathfrak{G}$ be a hierarchy with levels $L_1, L_2, \ldots, L_h$. For each $L_k$, $k = 1, 2, \ldots, h - 1$.

1. $L_{k+1}$ is outer dependent on $L_k$.
2. $L_{k+1}$ is not inner dependent with respect to all $x \in L_k$.
3. $L_k$ is not outer dependent on $L_{k+1}$.

Principle of Hierarchic Composition. If Axiom 3 holds, the global derived scale (rank order) of any element in $\mathfrak{G}$ is obtained from its component in the corresponding vector of the following:

$$
\psi_1(b) = 1,
\psi_2(L_2) = \psi_2(b^{-}/b),
\vdots
\psi_k(L_k) = \psi_k(L_k/L_{k-1})\psi_{k-1}(L_{k-1}), \quad k = 3, \ldots, h.
$$

Were one to omit Axiom 3, the Principle of Hierarchic Composition would no longer apply because of outer and inner dependence among levels or components which need not form a hierarchy. The appropriate composition principle is derived from the supermatrix approach of which the Principle of Hierarchic Composition is a special case (Saaty 1980).

A hierarchy is a special case of a system, the definition of which is given by:

Definition. Let $\mathfrak{S}$ be a family of nonempty sets $\mathfrak{S}_1, \mathfrak{S}_2, \ldots, \mathfrak{S}_n$, where $\mathfrak{S}_i$ consists of the elements $\{e_{ij}, j = 1, \ldots, m_i\}, i = 1, 2, \ldots, n$. $\mathfrak{S}$ is a system if
a pairwise comparison matrix $A$. Let $R_{\mathcal{M}(n)}$ be the set of $(n \times n)$ positive reciprocal matrices $A = (a_{ij}) = (P_C(A_i, A_j))$ for all $C \in \mathcal{C}$. Let $[0, 1]^n$ be the $n$-fold cartesian product of $[0, 1]$ and let $\psi : R_{\mathcal{M}(n)} \to [0, 1]^n$ for $A \in R_{\mathcal{M}(n)}$, $\psi(A)$ is an $n$-dimensional vector whose components lie in the interval $[0, 1]$. The triple $(R_{\mathcal{M}(n)}, [0, 1]^n, \psi)$ is a derived scale. A derived scale is a mapping between two numerical relational systems.

It is important to point out that the rank order implied by the derived scale $\psi$ may not coincide with the order represented by the pairwise comparisons. Let $\psi(A)$ be the $i$th component of $\psi(A)$. It denotes the relative dominance of the $i$th alternative. By definition, for $A_i, A_j \in \mathcal{Y}$, $A_i >_C A_j$ implies $P_C(A_i, A_j) > 1$. However, if $P_C(A_i, A_j) > 1$, the derived scale could imply that $\psi_i(A) > \psi_j(A)$. This occurs if row dominance does not hold, i.e., for $A_i, A_j \in \mathcal{Y}$ and $C \in \mathcal{C}$, $P_C(A_i, A_k) > P_C(A_j, A_k)$ does not hold for all $A_k \in \mathcal{Y}$. In other words, it may happen that $P_C(A_i, A_j) > 1$, and for some $A_k \in \mathcal{Y}$ we have

$$P_C(A_i, A_k) < P_C(A_j, A_k).$$

A more restrictive condition is the following:

**Definition.** The mapping $P_C$ is said to be consistent if and only if

$$P_C(A_i, A_j)P_C(A_j, A_k) = P_C(A_i, A_k) \quad \text{for all } i, j, \text{ and } k.$$  

(1)

Similarly the matrix $A$ is consistent if and only if $a_{ij}a_{jk} = a_{ik}$ for all $i, j, k$.

If $P_C$ is consistent, then Axiom 1 automatically follows and the rank order induced by $\psi$ coincides with pairwise comparisons.

**Hierarchic Axioms**

**Definition.** A partially ordered set is a set $\mathcal{S}$ with a binary relation $\leq$ which satisfies the following conditions:

(a) Reflexive: For all $x \in \mathcal{S}$, $x \leq x$.
(b) Transitive: For all $x, y, z \in \mathcal{S}$, if $x \leq y$ and $y \leq z$ then $x \leq z$.
(c) Antisymmetric: For all $x, y \in \mathcal{S}$, if $x \leq y$ and $y \leq x$ then $x = y$ (and $y$ coincide).

**Definition.** For any relation $x \leq y$ (read, $y$ includes $x$) we define $x < y$ to mean that $x \leq y$ and $x \neq y$. $y$ is said to cover (dominate) $x$ if $x < y$ and if $x < t < y$ is possible for no $t$.

Partially ordered sets with a finite number of elements can be conveniently represented by a directed graph. Each element of the set is represented by a vertex so that an arc is directed from $y$ to $x$ if $x < y$.

**Definition.** A subset $\mathcal{E}$ of a partially ordered set $\mathcal{S}$ is said to be bounded from above (below) if there is an element $s \in \mathcal{S}$ such that $x < s$ ($s$ $< x$) for every $x \in \mathcal{E}$. The element $s$ is called an upper (lower) bound of $\mathcal{E}$. We say that $\mathcal{E}$ has a supremum (infimum) if it has upper (lower) bounds and if the set of upper (lower) bounds $U$ ($L$) has an element $u_l$ ($l_l$) such that $u_l$ $\leq u$ for all $u \in U$ ($l_l$ $\geq l$ for all $l \in L$).

**Definition.** Let $\mathcal{S}$ be a finite partially ordered set with largest element $b$, $\mathcal{S}$ is a hierarchy if it satisfies the conditions:

(1) There is a partition of $\mathcal{S}$ into sets called levels $\{L_k, k = 1, 2, \ldots, h\}$, where $L_1 = \{b\}$.
(2) $x \in L_k$ implies $x^- \subseteq L_{k+1}$, where $x^- = \{x \mid x \text{ covers } y\}$, $k = 1, 2, \ldots, h - 1$.
(3) $x \in L_k$ implies $x^+ \subseteq L_{k-1}$, where $x^+ = \{y \mid y \text{ covers } x\}$, $k = 2, 3, \ldots, h$.

**Definition.** Given a positive real number $\rho > 1$ a nonempty set $x^- \subseteq L_{k+1}$ is said to be $\rho$-homogeneous with respect to $x \in L_k$ if for every pair of elements $x, y \in x^-$, $1/\rho \leq P_C(y_1, y_2) \leq \rho$. In particular the reciprocal axiom implies that $P_C(y_1, y_2) = 1$.

**Axiom 2.** Given a hierarchy $\mathcal{S}$, $x \in \mathcal{S}$ and $x \in L_k$, $x^- \subseteq L_{k+1}$ is $\rho$-homogeneous for $k = 1, \ldots, h - 1$.  

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(i) It is a directed graph whose vertices are $G_i$ and whose arcs are defined through the concept of outer dependence; thus

(ii) Given two components $G_i$ and $G_j \in G$ there is an arc from $G_i$ to $G_j$ if $G_j$ is outer dependent on $G_i$.

Therefore, many of the concepts derived for hierarchies also relate to general systems with feedback. Here one needs to characterize dependence among the elements. We now give a criterion for this purpose.

Let $D_A \subseteq G$ be the set of elements of $G$ outer dependent on $A \in G$. Let $\psi_{A,C}(A_j), A_j \in G$ be the derived scale of the elements of $G$ with respect to $A \in G$ for a criterion $C \in G$. Let $\psi_C(A_j)$, $A_j \in G$ be the derived scale of the elements of $G$ with respect to a criterion $C \in G$. We define the dependence weight

$$\phi_C(A_{ij}) = \sum_{A_j \in D_A} \psi_{A,C}(A_j) \psi_C(A_j).$$

If the elements of $G$ are inner dependent with respect to $C \in G$, then $\phi_C(A_{ij}) \neq \psi_C(A_{ij})$ for some $A_j \in G$.

Expectations are beliefs about the rank of alternatives derived from prior knowledge. Assume that a decision maker has a ranking, arrived at intuitively, of a finite set of alternatives $G$ with respect to prior knowledge of criteria $G$. He may have expectations about rank order.

Axiom 4 (Expectations).

$$G \subseteq \Phi - L_n, \quad \Phi = L_n.$$

This axiom simply says that those thoughtful individuals who have reasons for their beliefs should make sure that their ideas are adequately represented for the outcome to match these expectations; i.e., all alternatives are represented in the hierarchy, as well as all criteria. It neither assumes rationality of the process nor that it can only accommodate a rational outlook. People have many expectations that are irrational.

3. Results from the Axioms

Note that if $P_C$ is consistent, then Axiom 1 follows, i.e., consistency implies the reciprocal property. The first few theorems are based on this more restrictive property of consistency.

The theorems show that paired comparisons and the principal eigenvector are useful in estimating ratios. We use perturbation arguments to demonstrate that the principal eigenvector solution is the appropriate one to surface rank order from inconsistent data and that the eigenvector is stable to small perturbations in the data. These results are also obtained by means of graph theoretic arguments.

Let $R_{C(n)} \subset R_{M(n)}$ be the set of all $(n \times n)$ consistent matrices.

Theorem 1. Let $A \in R_{M(n)}, A \in R_{C(n)}$ if and only if $\text{rank}(A) = 1$.

Proof. If $A \in R_{C(n)}$, then $a_{ij}a_{jk} = a_{ik}$ for all $i, j$ and $k$. Hence, given a row of $A$, $a_{11}, a_{12}, \ldots, a_{1n}$, all other rows can be obtained from it by means of the relation $a_{ik} = a_{ik}/a_{ij}$ and $\text{rank}(A) = 1$.

Let us now assume that $\text{rank}(A) = 1$. Given a row $a_{ij}$ ($j \neq i, h = 1, 2, \ldots, n$), $a_{hi} = \text{Ma}_{hi}$ ($h = 1, 2, \ldots, n$) where $M$ is a positive constant. Also, for any reciprocal matrix, $a_{ij} = 1$ ($i = 1, 2, \ldots, n$). Thus, for $i = h$ we have $a_{hi} = \text{Ma}_{hi} = M$ and $a_{hj} = a_{ij}a_{hi}$ for all $i, j$ and $k$, and $A$ is consistent.

Theorem 2. Let $A \in R_{M(n)}, A \in R_{C(n)}$ if and only if its principal eigenvalue $\lambda_{\text{max}}$ is equal to $n$.

Proof. By Theorem 1 we have $\text{rank}(A) = 1$. 

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Also, all eigenvalues of $A$ but one vanish. Since $\text{Trace}(A) = \sum_{i=1}^{n} a_{ii} = n$ and $\text{Trace}(A) = \sum \lambda_k = n$, then $\lambda_{\max} \equiv \lambda_1 = n$.

If $\lambda_{\max} = n$,

$$n\lambda_{\max} = \sum_{i,j=1}^{n} a_{ij}w_jw_i^{-1} = n + \sum_{1 \leq i < j \leq n} \left( a_{ij}w_jw_i^{-1} + a_{ji}w_iw_j^{-1} \right) = n + \sum_{1 \leq i < j \leq n} (y_j + y_j^{-1}/\gamma_y) = n + \sum_{1 \leq i < j \leq n} (y_j + 1/\gamma_y).$$

Since $y_j + y_j^{-1}/\gamma > 2$, and $\lambda_{\max} = n^2$, equality is uniquely obtained on putting $y_j = 1$, i.e., $a_{ij} = w_i/w_j$. The condition $a_{ij}a_{jk} = a_{ik}$ holds for all $i$, $j$, and $k$, and the result follows.

**Theorem 3.** Let $A = (a_{ij}) \in \mathcal{R}_{C(n)}$. There exists a function $\psi = (\psi_1, \psi_2, \ldots, \psi_n)$, $\psi: \mathcal{R}_{C(n)} \rightarrow [0,1]^n$ such that

(i) $a_{ij} = \psi_i(A)/\psi_j(A)$,

(ii) The relative dominance of the $i$th alternative, $\psi_i(A)$, is the $i$th component of the principal right eigenvector of $A$.

(iii) Given two alternatives $A_i, A_j \in \mathcal{R}_i, A_i \succeq A_j$ if and only if $\psi_i(A) \geq \psi_j(A)$.

**Proof.** $A \in \mathcal{R}_{C(n)}$ implies that $a_{ij} = a_{ik}a_{kj}^{-1}$ for all $k$, and each $i$ and $j$. Also by Theorem 1, we have $\text{rank}(A) = 1$ and we can write $a_{ij} = x_i/x_j$, where $x_i, x_j > 0$ ($i, j = 1, 2, \ldots, n$). Multiplying $A$ by the vector $x^T = (x_1, x_2, \ldots, x_n)$ we have $Ax = nx$. Dividing both sides of this expression by $\sum_{i=1}^{n} x_i$ and writing $w = x/\sum_{i=1}^{n} x_i$ we have $Aw = nw$, and $\sum_{i=1}^{n} w_i = 1$. By Theorem 2 we have $n$ as the largest positive real eigenvalue of $A$ and $w$ as its corresponding right eigenvector. Since $a_{ij} = x_i/x_j = w_i/w_j$ for all $i$ and $j$, we have $\psi_i(A) = w_i$, $i = 1, 2, \ldots, n$, and $n$ and (i) and (ii) follow.

By Axiom 1, for $A \in \mathcal{R}_{C(n)}$, $A_i \succeq A_j$ if and only if $a_{ij} \geq 1$ for all $i$ and $j$, and hence we have $\psi_i(A) \geq \psi_j(A)$ for all $i$ and $j$.

It is unnecessary to invoke the Perron–Frobenius Theory to ensure the existence and uniqueness of a largest positive real eigenvalue and its eigenvector. We have already proved the existence of an essentially unique solution in the consistent case. A similar result follows using the perturbation argument given below.

**Theorem 4.** Let $A \in \mathcal{R}_{C(n)}$, and let $\lambda_1 = n$ and $\lambda_2 = 0$ be the eigenvalues of $A$ with multiplicity 1 and $(n - 1)$, respectively. Given $\varepsilon > 0$, there is a $\delta = \delta(\varepsilon) > 0$ such that if

$$|a_{ij} + \tau_{ij} - a_{ij}| = |\tau_{ij}| < \delta$$

for $i, j = 1, 2, \ldots, n$,

the matrix $B = (a_{ij} + \tau_{ij})$ has exactly 1 and $(n - 1)$ eigenvalues in the circles $|\mu - n| < \varepsilon$ and $|\mu - 0| < \varepsilon$, respectively.

**Proof.** Let $\varepsilon_0 = \frac{1}{2}(n)$, and let $\varepsilon < n/2$. The circles $C_1$: $|\mu - n| = \varepsilon$ and $C_2$: $|\mu - 0| = \varepsilon$ are disjoint. Let $f(\mu, A)$ be the characteristic polynomial of $A$. Let $r_j = \min\{f(\mu, A)\}$ for $\mu$ on $C_j$. Note that $\min\{f(\mu, A)\}$ is defined because $f$ is a continuous function of $\mu$, and $r_j > 0$ since the roots of $f(\mu, A) = 0$ are the centers of the circles.

$f(\mu, B)$ is a continuous function of the 1 + $n^2$ variables $\mu$ and $a_{ij} + \tau_{ij}$, $i, j = 1, 2, \ldots, n$, and for some $\delta > 0$, $f(\mu, B) \neq 0$ for $\mu$ on any $C_j$, $j = 1, 2, \ldots, n$, if $|\tau_{ij}| < \delta$, $i, j = 1, 2, \ldots, n$.

From the theory of functions of a complex variable, the number of roots $\mu$ of $f(\mu, B) = 0$ which lie inside $C_j$, $j = 1, 2$, is given by

$$n_j(B) = \frac{1}{2\pi i} \int_{C_j} \frac{f'(\mu, B)}{f(\mu, B)} d\mu, \quad j = 1, 2,$$

which is also a continuous function of the $n^2$ variables $a_{ij} + \tau_{ij}$ with $|\tau_{ij}| < \delta$. 119
For $B = A$, we have $n_1(A) = 1$ and $n_2(A) = n - 1$. Since $n_j(B)$, $j = 1, 2$, is continuous, it cannot jump from $n_j(A)$ to $n_j(B)$ and the two must be equal and have the value $n_1(B) = 1$ and $n_2(B) = n - 1$, for all $B$ with $|a_{ij} + r_{ij} - a_{ij}| < \delta$, $i, j = 1, 2, \ldots, n$.

**Theorem 5.** Let $A \in R_{(n)}$ and let $w$ be its principal right eigenvector. Let $\Delta A = (\delta_{ij})$ be a matrix of perturbations of the entries of $A$ such that $A' = A + \Delta A \in R_{M(n)}$, and let $w'$ be its principal right eigenvector. Given $\epsilon > 0$, there exists a $\delta > 0$ such that $|\delta_{ij}| < \delta$ for all $i$ and $j$, then $|w'_i - w_i| < \epsilon$ for all $i = 1, 2, \ldots, n$.

**Proof.** By Theorem 4, given $\epsilon > 0$, there exists a $\delta > 0$ such that if $|\delta_{ij}| < \delta$ for all $i$ and $j$, the principal eigenvalue of $A'$ satisfies $|\lambda_{max} - n| < \epsilon$. Let $\Delta A = \tau B$. Wilkinson (1965) has shown that for a sufficiently small $\tau$, $\lambda_{max}$ can be given by a convergent power series $\lambda_{max} = n + k_1 \tau + k_2 \tau^2 + \cdots$. Now, $\lambda_{max} \rightarrow n$ as $\tau \rightarrow 0$, and $|\lambda_{max} - n| = o(\tau) < \epsilon$.

Let $w$ be the right eigenvector corresponding to the simple eigenvalue $n$ of $A$. Since $n$ is a simple eigenvalue, $(A - nI)$ has at least one nonvanishing minor of order $(n - 1)$. Suppose, without loss of generality, that this lies in the first $(n - 1)$ rows of $(A - nI)$. Then from the theory of linear equations, the components of $w$ may be taken to be $w_1, w_2, \ldots, w_n$ where $w_i$ denotes the cofactor of the $(n, i)$ element of $(A - nI)$, and is a polynomial in $n$ of degree not greater than $(n - 1)$.

The components of $w'$ are polynomials in $\lambda_{max}$ and $\tau$, and since the power series expansion of $\lambda_{max}$ is convergent for all sufficiently small $\tau$, each component of $w'$ is represented by a convergent power series in $\tau$. We have

$$w' = w + \tau z_1 + \tau^2 z_2 + \cdots$$

and $|w' - w| = o(\tau) < \epsilon$.

By Theorems 4 and 5, it follows that a small perturbation $A'$ of $A$ transforms the eigenvalue problem $(A - nI)w = 0$ to $(A' - \lambda_{max}I)w' = 0$.

**Theorem 6 (Ratio Estimation).** Let $A \in R_{M(n)}$, and let $w$ be its principal right eigenvector. Let $\epsilon_{ij} = a_{ij}/w_j - 1$, for all $i$ and $j$, and let $1 - \tau < \epsilon_{ij} < 1 + \tau$, $\tau > 0$, for all $i$ and $j$. Given $\epsilon > 0$ and $\tau < \epsilon$, there exists a $\delta > 0$ such that for all $(x_1, x_2, \ldots, x_n)$, $x_i > 0$, $i = 1, 2, \ldots, n$, if

$$1 - \delta < x_i/x_j < 1 + \delta \quad \text{for all } i \text{ and } j, \quad (2)$$

then

$$1 - \epsilon < \frac{w_i / w_j}{x_i/x_j} < 1 + \epsilon \quad \text{for all } i \text{ and } j. \quad (3)$$

**Proof.** Substituting $a_{ij}/\epsilon_{ij} - 1$ for $w_i/w_j$ in (3) we have

$$\frac{|w_i / w_j - 1|}{x_i/x_j} = \frac{1}{\epsilon_{ij}} \left| \frac{a_{ij}}{x_i/x_j} - 1 \right| \leq \frac{1}{\epsilon_{ij}} \left| \frac{a_{ij}}{x_i/x_j} - 1 \right| + \frac{1}{\epsilon_{ij}} |1 - 1|.$$

By definition $\epsilon_{ij} = 1/\epsilon_{ij}$ for all $i$ and $j$, and we have

$$\frac{|w_i / w_j - 1|}{x_i/x_j} = \epsilon_{ij} \left| \frac{a_{ij}}{x_i/x_j} - 1 \right| + |\epsilon_{ij} - 1| < (1 + \tau)\delta + \tau.$$

Given $\epsilon > 0$ and $0 < \tau < \epsilon$, there exists a $\delta = (\epsilon - \tau)/(1 + \tau) > 0$ such that (2) implies (3).

This theorem says that if the paired comparison coefficient $a_{ij}$ is close to an underlying ratio $x_i/x_j$ then so is $w_i/w_j$ and may be used as an approximation for it.
THEOREM 7. Let $A = \{a_{ij}\} \in R_{M(n)}$. Let $\lambda_{\max}$ be its principal eigenvalue and let $w$ be its corresponding right eigenvector with $\sum_{i=1}^{n} w_i = 1$, then $\lambda_{\max} \geq n$.

PROOF. Let $a_{ij} = w_i w_j^{-1} \epsilon_{ij}$, $i,j = 1,2,\ldots,n$. Since $Aw = \lambda_{\max}w$, and $\sum_{i,j=1}^{n} a_{ij}w_j = \lambda_{\max}w$, we have

$$\lambda_{\max} - n = \sum_{i,j=1}^{n} a_{ij}w_j - n = \sum_{i,j} \epsilon_{ij} - n.$$  

By definition, the matrix $(\epsilon_{ij}) \in R_{M(n)}$. We have $\epsilon_{ii} = 1$ for all $i$, and $\epsilon_{ij} > 0$ for all $i$ and $j$. Hence, we have $\sum_{i,j=1}^{n} \epsilon_{ij} - n = \sum_{i \neq j} \epsilon_{ij} > 0$ and the result follows.

THEOREM 8. Let $A \in R_{M(n)}$. Let $\lambda_{\max}$ be the principal eigenvector of $A$, and let $w$ be its corresponding right eigenvector with $\sum_{i=1}^{n} w_i = 1$. $\mu = (\lambda_{\max} - n)/(n - 1)$ is a measure of the average departure from consistency.

PROOF. For $A \in R_{C(n)} \subset R_{M(n)}$, by Theorem 2 we have $\lambda_{\max} = n$, and hence, we have $\mu = 0$.

For $A \in R_{M(n)} - R_{C(n)}$, let $a_{ij} = w_i \epsilon_{ij}/w_j$ for all $i$ and $j$. We have

$$\lambda_{\max} = \sum_{j=1}^{n} a_{ij} w_j = \sum_{j-1}^{n} \epsilon_{ij},$$

$$n \lambda_{\max} = \sum_{i,j=1}^{n} \epsilon_{ij} = n + \sum_{1 \leq i < j \leq n} \left( \epsilon_{ij} + \frac{1}{\epsilon_{ij}} \right),$$

$$\frac{\lambda_{\max} - n}{n - 1} = -1 + \frac{1}{n(n - 1)} \sum_{1 \leq i < j \leq n} \left( \epsilon_{ij} + \frac{1}{\epsilon_{ij}} \right).$$

As $\epsilon_{ij} \to 1$, i.e., consistency is approached, $\mu \to 0$. Also, $\mu$ is convex in $\epsilon_{ij}$, since $(\epsilon_{ij} + 1/\epsilon_{ij})$ is convex, and has its minimum at $\epsilon_{ij} = 1$, $i,j = 1,2,\ldots,n$. Thus, $\mu$ is small or large depending on $\epsilon_{ij}$ being near to or far from unity, respectively, i.e., near to or far from consistency, and the result follows.

Note that $\sum_{i,j=1}^{n} a_{ij} w_j w_i^{-1} - n^2 = n(n - 1)\mu$ is also a measure of the departure from consistency.

It is also possible to show that $(A - nI)w = 0$ is transformed into $(A' - \lambda_{\max}I)w' = 0$ by means of graph theoretic concepts.

DEFINITION. The intensity of judgments associated with a path from $i$ to $j$ called the path intensity is equal to the products of the intensities associated with the arcs of that path.

DEFINITION. A cycle is a path of pairwise comparisons which terminates at its starting point.

THEOREM 9. If $A \in R_{C(n)}$, the intensities of all cycles are equal to $a_{ii}$, $i = 1,2,\ldots,n$.

PROOF. $A \in R_{C(n)}$, implies $a_{ij}a_{jk} = a_{ik}$ for all $i$, $j$ and $k$. Hence, we have $a_{ii} = a_{ij}a_{jk}a_{ki} = 1$ for all $i = 1,2,\ldots,n$. By induction, if $a_{ii},\ldots,a_{i\ldots\ldots},a_{ik} = 1$ for all $i_1\ldots\ldots\ldots i_{k-1}$, then $a_{ii},\ldots,a_{i\ldots\ldots\ldots i_k} = a_{ii}\ldots a_{i\ldots\ldots\ldots i_k} = 1$ and the result follows.

THEOREM 10. If $A \in R_{C(n)}$, the intensities of all paths from $i$ to $j$ are equal to $a_{ij}$.

PROOF. Follows from $a_{ij} = a_{ik}a_{kj}$ for all $i$, $j$ and $k$.

COROLLARY 1. If $A \in R_{C(n)}$, the entry in the $(i,j)$ position can be represented as the intensity of paths of any length starting with $i$ and terminating with $j$.

PROOF. Follows from the proof of Theorem 10.
COROLLARY 2. If \( A \in R_{C(n)} \), the entry in the \((i, j)\) position is the average intensity of paths of length \( k \) from \( i \) to \( j \), and \( A^k = n^{k-1}A \) \((k > 1)\).

PROOF. From Theorem 10, the intensity of a path of any length from \( i \) to \( j \) is equal to \( a_{ij} \).

An arbitrary entry of \( A^k \) is given by

\[
a_{ij}^{(k)} = \sum_{i_1=1}^{n} \sum_{i_2=1}^{n} \ldots \sum_{i_{k-1}=1}^{n} a_{i_1i_2i_3\ldots i_{k-1}j}.
\]

Since \( a_ia_j = a_{ij} \) for all \( i, j \) and \( k \) we have

\[
a_{ij}^{(k)} = \sum_{i_1=1}^{n} \sum_{i_2=1}^{n} \ldots \sum_{i_{k-1}=1}^{n} a_{ij} = n^{k-1}a_{ij}.
\]

By induction, if \( a_{ij}^{(k)} = n^{k-1}a_{ij} \) for \( k = 1, 2, \ldots, m - 1 \), for \( k = m \) we have

\[
a_{ij}^{(m)} = \sum_{i_1=1}^{n} \ldots \sum_{i_{m-1}=1}^{n} a_{i_1i_2i_3\ldots i_{m-1}j} = n^{m-1}a_{ij}.
\]

Hence, we have

\[
a_{ij} = \frac{1}{n^{m-1}} a_{ij}^{(m)} \quad \text{for all} \quad m \geq 1,
\]

and the result follows.

THEOREM 11. If \( A \in R_{C(n)} \) the entry in the \((i, j)\) position is given by the average of all path intensities starting with \( i \) and terminating with \( j \).

PROOF. By Corollary 2 of Theorem 10, we have

\[
a_{ij} = \frac{1}{n^{m-1}} \sum_{i_1=1}^{n} \ldots \sum_{i_{m-1}=1}^{n} a_{i_1i_2i_3\ldots i_{m-1}j}.
\]

Hence, we have

\[
a_{ij} = \lim_{m \to \infty} \frac{1}{n^{m-1}} a_{ij}^{(m)},
\]

and the result follows.

THEOREM 12. If \( A \in R_{C(n)} \) the scale of relative dominance is given by any of its normalized columns, and coincides with the principal right eigenvector of \( A \).

PROOF. Let \( A' \) be the \( j \)th column of \( A \).

\[
A \cdot A' = \left( \sum_{k=1}^{n} a_{ik} a_{kj} \right) \quad (i, j = 1, 2, \ldots, n),
\]

\[
= \left( \sum_{k=1}^{n} a_{ij} \right) = (na_{ij}) \quad (i, j = 1, 2, \ldots, n),
\]

and any column of \( A \) (whether or not it is normalized to unity) is a solution of the eigenvalue problem \( Ax = nx \). By Corollary 2 of Theorem 10 we have \( A^k = n^{k-1}A \). We have

\[
\psi(A) = \lim_{m \to \infty} \frac{1}{m} \sum_{k=1}^{n} A^k e = \lim_{m \to \infty} \frac{1}{m} \sum_{k=1}^{n} A e \frac{e^TA^k e}{e^T A e} = \frac{A e}{e^T A e}.
\]
Hence, we have
\[
\psi_i(A) = \sum_{j=1}^{n} a_{ij} \left/ \sum_{i,j=1}^{n} a_{ij} \right. = a_{ih} \left( \sum_{j=1}^{n} a_{ij} \right) \left/ \left( \sum_{i,j=1}^{n} a_{ij} \right) \right. = \frac{a_{ih}}{\sum_{i,j=1}^{n} a_{ij}}
\]
for all \(i\) and \(h\), and the result follows.

**Corollary.** The principal eigenvector is unique to within a multiplicative constant.

**Proof.** Follows from the proof of Theorem 12.

**Theorem 13.** If \(A \in R_{M(n)}\), the intensity of all paths of length \(k\) from \(i\) to \(j\) is given by
\[
\sum_{i_1=1}^{n} \sum_{i_2=1}^{n} \cdots \sum_{i_k-1=1}^{n} a_{i_1i_2} a_{i_2i_3} \cdots a_{i_{k-1}i_k}. \tag{1}
\]

**Proof.** It is known that the number of arc progressions of length \(n\) between any two vertices of a directed graph whose incidence matrix is \(V\) is given by \(V^n\). If in addition each arc has associated a number (\(\neq 1\)) representing the intensity (or capacity) of the arc, then \(V^n\) represents the intensity of all arc progressions of length \(n\) between two vertices.

Let \(V = A\). The entries of \(A^n\) give the intensity of all paths of length \(k\) between two vertices. Let \(A^k = (a_{ij}^{(k)})\). By construction we have
\[
a_{ij}^{(k)} = \sum_{i_1=1}^{n} \sum_{i_2=1}^{n} \cdots \sum_{i_k-1=1}^{n} a_{i_1i_2} a_{i_2i_3} \cdots a_{i_{k-1}i_k},
\]
and the result follows.

**Theorem 14.** Let \(A \in R_{M(n)}, A \not\in R_{C(n)}\). The principal right eigenvector of \(A\) is given by the limit of the normalized intensity of paths of length \(k\),
\[
w_i = \lim_{k \to \infty} \frac{a_{ih}^{(k)}}{\sum_{i=1}^{n} a_{ih}^{(k)}}, \quad i = 1, 2, \ldots, n,
\]
for all \(h = 1, 2, \ldots, n\).

**Proof.** It can be shown that
\[
\lim_{k \to \infty} \frac{a_{ih}^{(k)}}{\sum_{i=1}^{n} a_{ih}^{(k)}} = \lim_{k \to \infty} \frac{a_{is}^{(k)}}{\sum_{i=1}^{n} a_{is}^{(k)}}, \quad h, s = 1, 2, \ldots, n. \tag{4}
\]
The proof of this statement is given in Saaty and Vargas (1984b). Also we know that the principal right eigenvector of \(A\) is given by
\[
w_i = \lim_{k \to \infty} \frac{\sum_{i=1}^{n} a_{ih}^{(k)}}{\sum_{i=1}^{n} \sum_{h=1}^{n} a_{ih}^{(k)}}, \quad i = 1, 2, \ldots, n. \tag{5}
\]
Multiplying and dividing the right side of (5) inside the limit by \(\sum_{i=1}^{n} a_{ih}^{(k)}\) and rearranging the terms we have
\[
w_i = \lim_{k \to \infty} \left[ \frac{\sum_{h=1}^{n} \frac{a_{ih}^{(k)}}{\sum_{i=1}^{n} a_{ih}^{(k)}}}{\frac{\sum_{i=1}^{n} a_{ih}^{(k)}}{\sum_{i=1}^{n} \sum_{h=1}^{n} a_{ih}^{(k)}}} \right] = \sum_{h=1}^{n} \left[ \lim_{k \to \infty} \frac{a_{ih}^{(k)}}{\sum_{i=1}^{n} a_{ih}^{(k)}} \right] = \sum_{i=1}^{n} \left[ \lim_{k \to \infty} \frac{\sum_{i=1}^{n} a_{ih}^{(k)}}{\sum_{i, h=1}^{n} a_{ih}^{(k)}} \right].
\]
From (5) we have

\[ w'_i = \left[ \lim_{k \to \infty} \frac{a^{(k)}_{ih}}{\sum_{l=1}^{n} a^{(k)}_{ih}} \right] \sum_{h=1}^{n} \frac{\sum_{l=1}^{n} a^{(k)}_{ih}}{\sum_{j=1}^{n} a^{(k)}_{ij}} \]

and the result follows.

**Corollary.** Let \( A \in R_{M(n)} \), \( A \notin R_{C(n)} \). The principal right eigenvector of \( A \) is unique to within a multiplicative constant.

**Proof.** Follows from the proof of Theorem 14, and Theorem 5 in Saaty (1980).

**Theorem 15.** Let \( \mathcal{A} \) be a finite set of \( n \) elements \( A_1, A_2, \ldots, A_n \), and let \( C \in \mathcal{C} \) be a criterion which all the elements in \( \mathcal{A} \) have in common. Let \( A \) be the resulting matrix of pairwise comparisons. The \( i \)th component of the principal right eigenvector of the reciprocal pairwise comparison matrix \( A \) gives the relative dominance of \( A_i \), \( i = 1, 2, \ldots, n \).

**Proof.** By Theorem 14, the principal right eigenvector of \( A \) is given by

\[ w_i = \lim_{m \to \infty} \frac{\sum_{j=1}^{n} a^{(m)}_{ij}}{\sum_{j=1}^{n} a^{(m)}_{ij}} \]

for any \( h = 1, 2, \ldots, n \). By Theorem 7.13 in Saaty (1980) we have

\[ w_i = \lim_{m \to \infty} \frac{a^{(m)}_{ih}}{\sum_{j=1}^{n} a^{(m)}_{ij}} \]

Thus, the relative dominance of an alternative along all paths of length \( k \leq m \) is given by

\[ \frac{1}{m} \sum_{k=1}^{m} \frac{a^{(k)}_{ih}}{\sum_{i=1}^{n} a^{(k)}_{ih}} \]

Let

\[ s_k = \frac{a^{(k)}_{ih}}{\sum_{i=1}^{n} a^{(k)}_{ih}} \]

and

\[ t_m = \frac{1}{m} \sum_{k=1}^{m} s_k \]

It can be shown that if \( \lim_{k \to \infty} s_k \) exists then \( \lim_{m \to \infty} t_m \) also exists and the two limits coincide. By Theorem 14, we have \( s_k \to w \) as \( k \to \infty \), where \( w \) is the principal right eigenvector of \( A \). Thus \( t_m \to w \) as \( m \to \infty \) and \( \psi(A) = w_i \), \( i = 1, 2, \ldots, n \).

This theorem highlights the fact that the right eigenvector gives the relative dominance (rank order) of each alternative over the other alternatives along paths of arbitrary length. It holds for a reciprocal matrix \( A \) which need not be consistent.

4. Relative and Absolute Measurement-Rank Preservation

The AHP can be used to make relative measurement through paired comparisons (scaling) of criteria and of alternatives, or to make absolute measurement (scoring) of the alternatives with respect to the criteria. The former is now familiar. The latter has been used when the number of alternatives is large and the decision is standard such as admitting students to a college based on well-established criteria whose weights are not affected by the number of students and their scores.

When the AHP uses paired comparisons it assumes structural dependence of the criteria on the number of alternatives and on their priorities. As a result, when alternatives are scaled through paired comparisons, adding a new alternative can
change the relative ranking of the old ones when the judgments are inconsistent or when several criteria are used. Under a single criterion rank never changes with the addition of a new alternative when the judgments are consistent (Saaty and Vargas 1984a). Note that if structural criteria are an integral part of a decision theory, the weights of these criteria would change with the introduction or deletion of alternatives and hence both the priorities and the ranks of the old alternatives can change. Thus structure is an important aspect of all systems and needs to be considered for better understanding of decisions. How to interpret such structural criteria has been covered in other works by this author now in process of publication.

If, in spite of structural dependence, for some practical reason one insists that the old rank remain in place and a new alternative be added, the new alternative can be measured by comparing it with one of the original ones and assigning it the appropriate value under each criterion without renormalizing. Normalization is then applied to the composite result. The priorities will change, but the ranking will be the same.

With absolute measurement there can be no rank reversal under a single or under multiple criteria. One compares the criteria, with respect to the goal, subcriteria with respect to the criteria and then the intensities of the subcriteria such as: excellent, very good, good, average, below average, poor, and very poor, with respect to each subcriterion. This yields a set of priorities for the intensities of the subcriteria. Each alternative is then scored with respect to each subcriterion by selecting the appropriate intensity. Once the weights of the intensities have been established the question of consistency in scoring the alternatives does not occur. Finally one adds all the priorities of the intensities to obtain a score for the alternative. In the end, these priorities may be normalized for all the alternatives.

5. Conclusion

We conclude with general remarks about the use of the AHP.

Because the AHP does not separate intangible factors from tangible ones and conducts its measurement by making pairwise comparisons, it is a useful way for analysis and decision making in complex social and political problems. In general, other methods such as multiattribute utility theory would first quantify individual intangible factors before calculating utility functions.

The AHP is also useful when many interests are involved and a number of people participate in the judgment process. Here debate may be to no avail and several answers must be developed. The results would then be weighted by the priority of the corresponding individuals according to that individual's relevance to the problem. These priorities are derived by extending the hierarchy upwards to include the individuals and criteria for evaluating them, with their assistance or participation when possible.

Judgments from different people on a single comparison must satisfy the reciprocal property for the group. This implies that these judgments must be synthesized into a single judgment according to the geometric mean (Aczel and Saaty 1983).

The AHP deals with problem decomposition in a systematic way. It requires that elements in each level be homogeneous, decreasing in size from the top to the bottom level of the hierarchy. While there is flexibility in structuring a problem, it is clear from the start that one proceeds by arranging the issues in descending (or ascending) order. It is also possible through the AHP to structure a problem which has dependencies and feedback to set priorities and make a choice.

Most of the difficulties encountered in using the AHP relate to the need for judgments. If a problem is complex and requires careful analysis, then time would be needed to elicit judgments. However, people can become tired and need to return to
the process after some rest. The more complex problems have needed nearly two days for this kind of participation. Furthermore, the AHP calls for occasional repetition of the process to make sure that the participants have not changed their minds dramatically. Patrick Harker of Wharton has recently developed a procedure for shortening the judgmental process.

It should now be clear that designing the analytic hierarchy, like the structuring of a problem by any other method, necessitates a substantial knowledge of the system in question. A strong aspect of the AHP is that the knowledgeable individuals who supply judgments for the pairwise comparisons usually also play a prominent role in specifying the hierarchy. Another key aspect in structuring a hierarchy is that any element in a level can be compared with respect to some elements in the level immediately above. The hierarchy need not be complete; that is, an element at an upper level need not function as a criterion for all the elements in the lower level. It can be partitioned into nearly disjoint subhierarchies sharing only a common topmost element. Thus for instance, the activities of separate divisions of an organization can be structured separately. The analyst can insert and delete levels and elements as necessary to clarify the task or to sharpen the focus on one or more areas of the system.

The AHP has already been successfully applied in a variety of fields. These include: a plan to allocate energy to industries; designing a transport system for the Sudan; planning the future of a corporation and measuring the impact of environmental factors on its development; design of future scenarios for higher education in the United States; the candidacy and election processes; setting priorities for the top scientific institute in a developing country and the faculty promotion and tenure problem (Saaty 1982, Wind and Saaty 1980, Töp 1986). The use of the AHP has been facilitated greatly by the availability of the microcomputer software package Expert Choice (1985).

References


