Volume 1

Development of a Method to Forecast Future Systems in the Forest Engineering Value Chain

By

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Declaration

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

M. P. Brink

Abstract

The objective of this study is to develop a new method which can be used to forecast the Forest Engineering value chain. The method is then applied in the South African context in order to validate the use thereof. Finally, the South African results are used to propose strategies, which the industry should pursue in the future.

To forecast the future an understanding of the past is required. To this end, the historical development of Forest Engineering is discussed, both globally and in South Africa. The current *status quo* in Forest Engineering in South Africa was determined through a national survey of plantations larger than 200 ha. The results are reflected in Chapter 2. Because of the importance of globalisation and technology, Chapter 3 gives a literature review of relevance of technology in today's business world, including various forecasting techniques that are relevant to the study. These techniques are a combination of traditional forecasting methods, technology forecasting methods and strategic planning methods. Various approaches to financial analysis have also been discussed, in order to determine the soundest method of comparing various forest engineering systems with each other. This includes an overview of traditional machine cost calculations.

The core of the study lies in the combination of these methodologies into a useful method, which is particularly suited to forecasting the Forest Engineering value chain. Such a method is developed in Chapter 4, based on the literature review of forecasting methodologies.

The method is then validated in Chapter 5, through the application thereof in the South African forestry industry. Global trends are established with the use of a Delphi study. This technique uses a panel of experts who give their views on future developments on a multiple round basis. The study then evaluates 14 Forest Engineering systems for pine sawtimber, pine pulpwood and *Eucalyptus* pulpwood, based on various scenarios of the future. The scenario matrix is based on the future cost of labour *vs.* the future cost of machinery.

Finally, a strategy is proposed on how the South African forestry industry should prepare itself for the future.

Samevatting

Die doelwit van die studie is om 'n nuwe metode te ontwikkel waarmee 'n vooruitskatting van die Bosingenieurswese waardeketting gemaak kan word. Die metode word dan in die Suid-Afrikaanse konteks toegepas om die geldigheid daarvan te beproef. Die Suid-Afrikaanse resultate word voorts gebruik om 'n nasionale Bosingenieurswese strategie voor te stel vir die bedryf.

Dit is nodig om die verlede te verstaan, voor die toekoms vooruitgeskat kan word. Om dié rede is die historiese ontwikkeling van bosingenieurswese bespreek, in beide 'n internasionale, sowel as 'n Suid Afrikaanse konteks. Die huidige *status quo* van Bosingenieurswese in Suid Afrika is vasgestel deur 'n nasionale opname waarby plantasies van groter as 200 ha ingesluit is. Die resultate van die opname word weergegee in Hoofstuk 2. As gevolg van die belangrikheid van beide globalisering en tegnologie, is 'n literatuur studie ingesluit in Hoofstuk 3 oor die relevansie van tegnologie in die besigheidswêreld van vandag, asook en 'n bespreking van verskeie vooruitskattingstegnieke wat in die studie gebruik kan word. Hierdie vooruitskattinge is 'n kombinasie van tradisionele vooruitskattings tegnieke, tegnologie vooruitskattingstegnieke en tegnieke wat gebruik word vir strategiese beplanning.

Verskeie benaderinge tot finansiële analise is ook bespreek. Dit sluit tradisionele masjienkoste berekening in. Die rede hiervoor is om vas te stel watter metode die mees geskikte sou wees om verskeie Bosingenieurswese sisteme met mekaar te vergelyk.

Die kern van die studie lê in die kombinasie van hierdie metodes om 'n bruikbare metode te ontwerp om die Bosingenieurswese waardeketting vooruit te skat. Hierdie ontwerp word in Hoofstuk 4 bespreek.

Die metode word in Hoofstuk 5 beproef, deur die toepassing daarvan op die Suid Afrikaanse bosbedryf. Internasionale bosingenieurswese tendense is vasgestel deur middel van 'n Delphi studie. Hierdie vooruitskatting maak gebruik van 'n paneel van kundiges wat hulle siening oor die toekoms uitspreek deur verskeie rondtes van vrae wat aan hulle gestel word.

Die studie evalueer hierna 14 Bosingenieurswese sisteme vir denne saaghout, denne pulphout en *Eucalyptus* pulphout, gebaseer op 'n scenario-analise van die toekoms. Die scenario matriks is gefundeer op die toekomstige koste van arbeid teenoor die toekomstige koste van masjinerie.

As 'n finale stap word voorgestel hoe die Suid Afrikaanse bosbedryf kan voorberei om die toekoms tegemoet te gaan.

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List of Abbreviations

AF & PA	American Forest and Paper Association
AIDS	Acquired immunodeficiency syndrome
ATO	African Timber Organisation
Aust $	Australian Dollar
CAN $	Canadian dollar
CEO	Chief Executive Officer
CIFOR	Center for International Forestry Research
CSA	Canadian Standards Organisation
CSIR	Council for Scientific and Industrial Research
CTI	Central tyre inflation
CTL	Cut-to-length
CTLL	Labour-intensive cut-to-length
CTLM	Mechanised cut-to-length
DCF	Discounted cash flow
DDCL	Delimber/Debarker/ Chipper/ Loader
DTT	Drive-to-tree
DWAF	Department of Water Affairs and Forestry
E. Cape	Eastern Cape
E. Tvl	Eastern Transvaal
EMAS	Eco Management and Auditing Scheme
EU	European Union
F.D.	Forest Department
F.T.S.	Forest Technical Survey
FAO	Food and Agriculture Organisation
FB	Feller buncher
FB/GS	Feller Buncher / Grapple Skidder
FERIC	Forest Engineering Research Institute of Canada
FESA	Forest Engineering Southern Africa
FIG	Figure
FMG	Forest Machines Group
FOA	Forest Owners Association
FSC	Forest Stewardship Council
FV	Future value

GPS	Global Positioning Systems
ha	Hectare
Harv/Forw	Harvester / Forwarder
HIV	Human immunodeficiency virus
HR	Human Resources
HW	Hardwood
IRR	Internal rate of return
ISO	International Standards Organisation
ITTO	International Tropical Timber Organisation
K/Natal	KwaZulu Natal
MFPT	Multi functional project team
MCC	Machine cost calculation
Mpl.	Mpumalanga
N.Tvl	Northern Transvaal
NGO's	Non-Governmental Organisations
NP	Northern Province
NPV	Net present value
NQF	National Qualifications Framework
NZ $	New Zealand dollar
OL	Own labour
OSB	Oriented strand board
PESTE	Political, Economical, Social, Technological and Environmental
PI	Profitability index
ppmv	parts per million by volume
PV	Present value
R	Rand
R&D	Research and Development
R&M	Repairs and maintenance
R/L	Rand per litre
RSA	Republic of South Africa
S.Cape	Southern Cape
S.Tvl	Southern Transvaal
SABT	South African Bantu Trust
SAQA	South African Qualifications Authority

SBU	Strategic Business Unit
SFI	Sustainable Forestry Initiative
SFM	Sustainable forest management
SFM	Sustainable Forest Management
Spp.	Species
STT	Swing-to-tree
SW	Softwood
Swiss F	Swiss Franc
SWOT	Strengths, Weaknesses, Opportunities, Threats
TL	Tree-length
TLB	Tractor loader backhoe
US	United States
us	Unit standard
US $	United States Dollar
USA	United States of America
USDA	United States Department of Agriculture
W. Cape	Western Cape
WWF	Worldwide Fund for Nature

1. INTRODUCTION

1.1 The purpose of the study

The objective of the study is to develop a new method, which can be used to forecast the systems in the Forest Engineering value chain at some point in time in the future.

The method is then applied in the South African context to prove the versatility of the method in practice. Even though the actual results of the forecast will only become known in the future, the application of the proposed methodology can be tested. The method is used to develop strategies for Forest Engineering systems in South Africa to meet the demands of the future.

1.2 Scope of the study

The study takes the approach that the timber harvesting portion of the value chain will be driving future change. Even though the proposed method can be applied to transport, this study includes only the timber harvesting portion within the environmental scanning exercise. The inclusion of transport in this portion of the method would not have made any contribution to the testing of the method. Due to the importance of evaluating the whole value chain, in order to reach realistic assumptions, the transport function is included in the financial analysis of the value chain. The transport modes are also tailored to compliment the remainder of the activities in the value chain.

The study includes only commercial plantations (large forestry companies and state-owned plantations). This covers some 76% of the South African plantation area. The small grower industry is therefore excluded. Within these commercial plantation areas, the study covers the clearfelling of pine pulpwood, *Eucalyptus* pulpwood and pine sawtimber. Thinning operations are excluded. The Forest Technical Survey, which forms part of this study, shows that in excess of 90% of all harvesting operations in South Africa use ground-based systems. The study therefore excludes the future changes in cable yarding. However, the global view on the possible expansion of cable yarding is described and a forecast is given of the number of yarders expected in South Africa in 2010.

The method developed in this study can be applied to any company within any region, in any one country, or subcontinent, for a forecasting period of up to 10 years. A generic method has therefore been developed to forecast the systems in the Forest Engineering value chain, which has been tested through its application in the South African industrial forestry sector.

1.3 The Hypothesis for the Study

The following hypotheses will be tested in the study:

The null hypothesis for this study is:

H_0 : As a result of the development of a forecasting method unique to the systems in the Forest Engineering value chain, the future systems in the Forest Engineering value chain cannot be forecast for South Africa in the year 2010.

This is tested against the alternative hypothesis:

H_A : As a result of the development of a forecasting method unique to the systems in the Forest Engineering value chain, the future systems in the Forest Engineering value chain can be forecast for South Africa in the year 2010.

1.4 The approach to the study

Chapter 1 gives the background information regarding the study. This includes the objective of the study, the importance of the study, an overview of relevant definitions and a summary of the factors that influence the systems in the Forest Engineering value chain. The Chapter concludes with an overview of global forestry and South African forestry. This is necessary in order to understand the context of the environment, within which a forecasting method is to be developed.

Without a sound understanding of the past, the future cannot be explored. For this reason, Chapter 2 focuses on the past Forest Engineering developments, both globally and in South Africa. Two distinct and diverging developments took place in harvesting systems. North America is the birthplace of tree length (TL) systems, with the majority of the equipment used in TL systems being developed and manufactured in the USA and Canada. On the other hand, the Scandinavian countries, primarily Sweden and Finland, developed machines working in cut-to-length (CTL) systems. A TL system primarily combines a feller buncher and a grapple skidder, while a CTL system consists of a harvester and forwarder combination. An overview of these two developmental patterns in North America and Scandinavia is thus given. The chapter then moves to the developments in South Africa and includes a comprehensive survey, which was conducted in 1997. The survey forms the point of departure for the forecasting exercise completed in Chapter 5. It is a comprehensive exercise, which includes all forestry areas in excess of 200 ha in South Africa. The chapter is concluded with an overview of future global Forest Engineering developments. This is necessary, so as to gain a broad overview of existing literature on the subject.

After the overview given in Chapter 2, it is evident that Forest Engineering is technology-driven. Traditional Forest Engineering courses include very little on technology, its development and how to forecast this development. For this reason it is necessary to give a comprehensive overview of the subject. Chapter 3 commences with an overview of technology and how it is to be managed. It includes innovation, waves and cycles in technology and the management of technology strategies within industries and organisations. This background information is critically important to allow for a sound understanding of what is to be considered when selecting forecasting techniques and how an industry or organisation should manage towards the expected future outcomes. Without an implementation strategy, the forecast loses most of its value. Chapter 3 then proceeds to evaluate various forecasting techniques and their relevance to Forest Engineering. After discussing each technique, a short conclusion is given as to how the technique could be included in the development of a forecasting method. Finally, the Chapter concludes with a discussion of approaches to the costing of the Forest Engineering value chain. The techniques are limited to Discounted Cash Flow (DCF) techniques and those used in traditional machine cost calculations (MCC). This is required to select the most appropriate method of selecting the preferred value chain for the future.

Chapter 4 focuses on the development of a method that successfully combines the various forecasting techniques. The Chapter starts with a description of the principles of forecasting and how forecasting techniques are to be used in order to develop a sound forecasting method. With this as background the relevant Forest Engineering factors are identified, which need to be considered in the development. The chapter concludes with a systematic discussion of why a specific technique was selected and how it is to be applied.

The forecasting method, developed in Chapter 4, is applied in Chapter 5, to verify its validity. A forecasting period is defined, followed by a refinement of the forecasting method, specifically for the South African forecast. Thereafter a systematic implementation of the methodology follows. The forecast includes a comprehensive Delphi study to identify future global timber harvesting change drivers, future harvesting systems, the role of contractors and the human resource requirements of managers and contractors. It also includes an analysis of machine substitution curves by using the Fisher-Pry technique. The substitution is specifically targeted at identifying the substitution of TL machines by CTL machines.

A comprehensive environmental scanning exercise is included for South Africa, focussing on factors, which will influence the systems in the Forest Engineering value chain. With this as background, a scenario analysis is completed, culminating in the identification of 14 potential systems in the Forest Engineering value chain for South Africa. The scenario analysis gives a sound platform for an in-depth costing exercise of the 14 systems and their relevance to each scenario. The costing exercise required the development of a DCF model, which was used for the ranking of alternative systems within each scenario. The chapter concludes with the required strategies by the forestry industry to manage towards the required outcomes for the future. Projected machine numbers for the preferred systems are also given. The flow chart in figure 1.1 describes the logic of the process followed throughout this study. New information that has been generated is highlighted in bold.

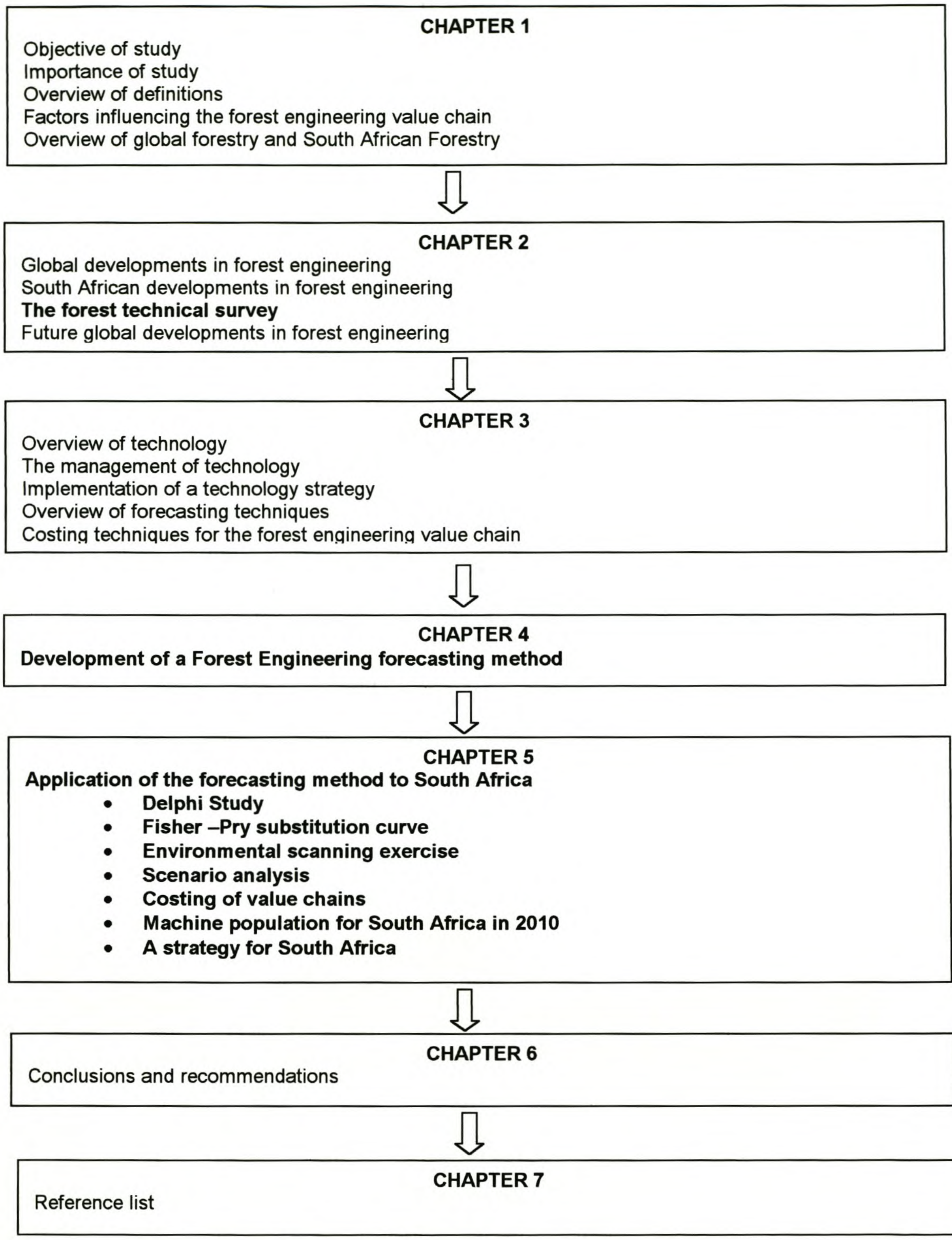


Figure 1.1: Flowchart depicting the process followed in this study

1.5 Definitions

1.5.1 Forest Engineering

Forest engineering is the application of engineering principles to design, implement, operate, and continuously improve technical systems needed in the forests. The forest engineer provides forest plans and operations that are:

- *environmentally sound* considering impacts on the natural environment and efficient use of natural resources including non-renewable materials, renewable materials, water, energy, and space,
- *technically feasible* considering the physical laws, engineering disciplines, and environmental relationships of the forest,
- *economically viable* considering the costs and benefits of short and long range consequences, and
- *institutionally feasible* considering the laws and regulations governing the forest operation, landowner objectives, and social values.

Important forest engineering skills focus on problem solving, analyses using quantitative methods, and professional communication. Throughout the world, forest engineers are planning and implementing forest activities such as timber harvesting, site preparation for regeneration, enhancing wildlife habitats in forests, developing forest transportation systems, building forest structures and facilities, designing new operating systems and the associated machinery, analysing economic undertakings, developing forestry workforces, maintaining quality control, promoting safety and health, enforcing environmental standards, and various other engineering tasks in the forest environment. Forest engineering blends forestry and engineering knowledge and draws from the physical sciences, natural sciences, forestry disciplines and various engineering disciplines (Kellogg, 1999).

The discipline of Forest Engineering therefore includes all activities required to transfer the standing tree, i.e. the material that is suitable for conversion (stem wood, branch wood, wood from the roots, bark and residues) into a suitable product for further processing, as depicted in Figure 1.2.

Various terminologies are used throughout the world to describe the process of felling, extracting, merchandising, loading and unloading of timber. Some of these are logging, harvesting and transport, exploitation and forest engineering. Even though forest engineering is strictly speaking a discipline, it is interchangeably used to describe the supply chain within the discipline, as is the case in South Africa. For this reason, the term "Forest Engineering" is used to define the relevant supply chain in this dissertation.

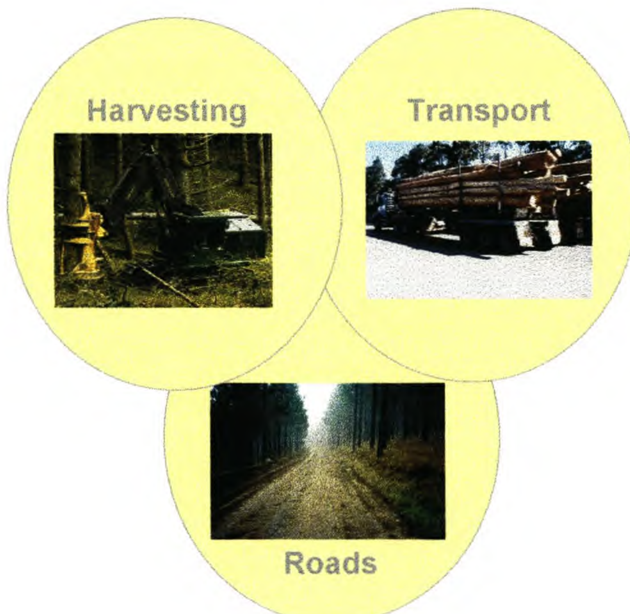


Figure 1.2: The elements within Forest Engineering

Forest Engineering therefore deals with the inter-relationships between harvesting, roads and transport, but also includes an understanding of the relationships between labour, technology, the forest product industries, people and the environment. Figure 1.3, clearly depicts these inter-relationships between various disciplines and activities which contribute to the growing of a healthy, sustainable forest and utilising the fibre on an economical basis.

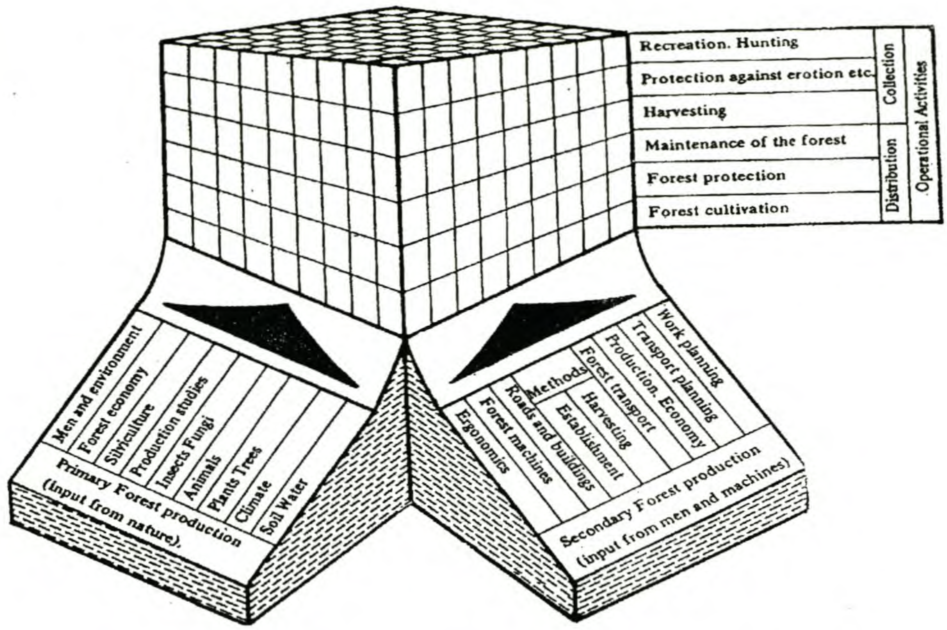


Figure 1.3 Forestry comprising biological and technical production (Samset, 1982)

1.5.2 The value chain

The term value chain describes a way of looking at a business as a chain of activities that transform inputs into outputs that customers value (Pearce and Robinson, 2000). Other terms are also used to describe a business chain, such as the supply chain and the logistics chain. These terms are used interchangeably within the forestry environment. The term "value chain" is unique in the sense that it includes both costs and value of the final product. For this reason value chain is used in this dissertation. The activities performed in competing in a particular industry can be grouped into specific categories within the value chain, as shown in Figure 1.4.

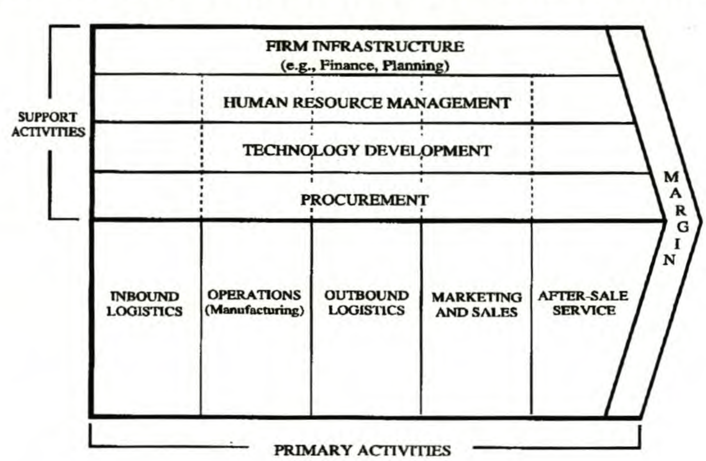


Figure 1.4: The value chain (Porter, 1990)

Primary activities, or line functions, are those activities involved in the physical creation of the product, the marketing thereof, the transfer to the buyer and after-sales support. Support activities, or staff functions, assist the firm as a whole by providing infrastructure inputs that allow the effective execution of the primary activities (Pearce and Robinson, 2000). Strategy guides the way a firm performs individual activities and organises its entire value chain. A firm is more than the sum of its activities. A firm's value chain is an inter-dependent system or network of activities, connected by linkages. Linkages occur when the way one activity is performed affects the cost effectiveness of other activities. Linkages often create trade-offs in performing different activities that must be optimised. Gaining competitive advantage requires that a firm's value chain be managed as a system rather than a collection of separate parts. Reconfiguring the value chain, by relocating, re-ordering, regrouping or even eliminating activities, is often the proof of major improvement in competitive position (Porter, 1990).

1.5.3 The Forest Engineering value chain

The Forest Engineering value chain refers to a portion of the forestry value chain. It includes the sequence of activities required to convert a standing tree into a marketable product and the delivery thereof to the primary processor. Figure 1.5 describes the Forest Engineering value chain.

<table>
<tr><td colspan="5">▪ Tactical and operational planning
▪ Sound measuring of performance against set targets</td></tr>
<tr><td colspan="5">▪ Incentive systems for machine operators and remuneration of employees
▪ Sound recruitment and selection systems for all employees</td></tr>
<tr><td colspan="5">▪ Use of the most appropriate machines and equipment globally available</td></tr>
<tr><td colspan="5">▪ Purchase prices of machines and equipment
▪ Price of fuel and oil
▪ R&M costs of machines and equipment</td></tr>
<tr><td>Inbound logistics
▪ Machine relocation
▪ Labour transport</td><td>Operations
Harvesting of standing trees</td><td>Outbound logistics
Transport of logs or chips to processor</td><td>Marketing & Sales
Supplying logs or chips:
▪ In full
▪ On time
▪ Within spec.</td><td>After-sale service
▪ Quality control on logs/chips</td></tr>
</table>

Figure 1.5: The Forest Engineering value chain

The Forest Engineering value chain consists of the following activities in the forestry environment:

- felling of standing trees
- debranching of felled trees
- cross-cutting or merchandising of tree lengths into a marketable product
- loading of products onto a truck to transport the commodity to a mill or factory
- transporting of the commodity
- unloading the commodity at the customer
- the value chain could also include the debarking of logs and/or the chipping thereof for the production of pulp.

The sequence of activities are not always the same and the unique combination of activities create the synergy in the value chain to use the most cost effective overall system to produce logs or chips. Figure 1.6 gives a matrix of such a value chain, commonly referred to as a harvesting system, applicable to pine sawtimber.

1.6 The importance of Forest Engineering in forestry

A summary of the major aspects of Forest Engineering, showing its importance as described by Brink and Conradie (2000), is given below:

(a) Forest Engineering constitutes 60% to 80% of the operational budget of forestry, and as such requires that operations be performed cost-effectively.
(b) Forest Engineering has a significant influence on the environment and the necessary steps are required to minimise the environmental impacts. With the advent of the certification of plantations some years ago, there has been a strong inclination towards environmentally sound Forest Engineering with regard to the environment, social aspects, and economics.
(c) From a forestry perspective, harvesting, roads and transport operations interact directly with the primary processing market. The influence thereof on customer satisfaction and value added products is significant.

A sound working knowledge of methods and equipment that can be employed in harvesting operations is of vital importance. A study of harvesting principles and practices in forestry is therefore essential.

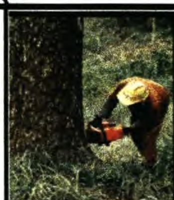
Locality / Activity	Stand	Extraction road	Roadside landing	Forest road	Sawmill
Fell					
Extract					
X-cut					
Stack/Load					
Transport					
Unload					

Figure 1.6: A matrix illustrating the Forest Engineering value chain applicable to pine sawtimber

1.7 Factors that influence the Forest Engineering value chain

1.7.1 Planning

Sound long-, medium- and short-term planning allows the forester to be more flexible in the dynamic world of today. Brink and Kellogg (2000) emphasises that only benefits can be gained by measuring field results to pre-set targets, which themselves are based on sound planning techniques.

Zaremba (1976) underlines the unique problems in harvesting and the fact that this is the most costly factor in forestry operations. Success mainly depends (apart from road location and the espacement of roads) on the proper selection of extraction routes and hence optimal log disposal along roads and landings in convenient places for loading. A well-planned harvesting road system is laid out in such a way that the roads "tap" the timbered area and keep skidding distances down to the practical minimum.

1.7.2 Machines and equipment

Forest Engineering operations are, by nature, more capital intensive than silviculture. Machines and equipment therefore constitute a significant part of the total costs and thus require special focus. The most important issues include:

- Making full use of the productive time available and therefore understanding the value chain from a systems perspective.
- Keeping the average age of the production fleet to an acceptable level.
- Operating machines responsibly, both in terms of terrain/machine matching and machine maintenance (Parsons, 2000).

1.7.3 Quality of operations

The objective is always the lowest total cost of the whole value chain. Operations should be executed in such a manner that:

- fibre resources are optimally utilised;
- customer requirements are carefully considered within a framework of the relevant log specifications;
- safety procedures are strictly adhered to;
- cognisance is taken of Forest Engineering's inter-relation with other upstream activities (e.g. re-establishment and trees remaining after a thinning).

1.7.4 Work science

Brink and Conradie (2000) stress the importance of a motivated and healthy workforce in order to run a successful forestry operation. Some harvesting operations are still very labour intensive in South Africa today. South Africa is also the country that has the highest incidence of HIV/AIDS in the world today (Whiteside and Sunter, 2000).

A sound working knowledge of methods and equipment, which can be employed in harvesting operations, is thus of vital importance. Even more important is the need to understand the dynamics within the harvesting workforce and the future knowledge and skills required by the workforce in order to optimise the whole value chain. To pursue a highly mechanised strategy without skilled operators and state-of-the-art mechanical back-up could lead to failure.

1.7.5 Environmental factors

The harvesting of timber, the building of forest roads, and the use of vehicles on forest roads have the greatest environmental impact of all forestry activities in a plantation environment.

There is a global commitment to improve the management of forests. This improvement entails a rebalancing of forest management objectives, which is bringing about changes in the way forests are managed and, in some places, a reallocation of forest areas to alternate uses. This may result in reduced timber harvests in natural forests, but, on the other hand, increased production of other non-timber goods and services. Implementing Sustainable Forest Management (SFM) may lead to reduced volumes harvested in the short-term, yet there is an expectation that it will increase wood supply over the long-term.

Natural forest management is currently being affected by changes in resource availability, developments in management objectives and practices, and institutional changes which have led to a more diverse set of forest managers (FAO, 1999).

1.7.6 Technology

Technological developments are playing an increasingly dominant role in Forest Engineering. The rapid technological developments in computers have also improved the effectiveness and the efficiency of these machines. Chapter 2 covers this subject in detail.

1.8 The need for the study

Alberts (1996) stated: "If, 20 years ago, the world was the size of a hall which could seat 400 people, then it is now the size of a tennis ball." Change is driving the world of today and it has become imperative that forestry, and specifically the costly Forest Engineering part of the business, approaches the world of today differently than it did in the past. Due to the long-term nature of forestry, foresters are inclined to ignore the current global dynamism and to focus on that which is known and with which they are comfortable. The last decade in particular has seen an international intensification of social pressures on the forestry fraternity. This has been most prevalent in the perceived environmental impacts that forestry brings to bear, whether these views are scientifically justified, or otherwise. These pressures are based primarily on media pressure and what the public views as aesthetically acceptable or unacceptable.

Internationally, Forest Engineering is predominantly the technology driven sector of the forest industry, with the majority of the harvesting systems in the industrialised world now mechanised.

Forestry is also by and large in the hands of large industrial organisations due to a progressive consolidation of forestry assets over the globe in the last few years. However, evaluation techniques of harvesting systems have traditionally only focussed on the technical aspects thereof, using conventional costing systems when evaluating a machine or a combination of machines in the harvesting system.

Within the current changing world, South Africa is also going through a period of rapid change, specifically due to the democratisation of the country in 1994. The forecasting method used should therefore be able to forecast the harvesting methods that will be used in South Africa in 2010 and thereby give the industry the necessary direction. Some recent changes in South Africa, which need to be mentioned are:

- the huge swing from own operations to contractor operations;
- the change in plantation ownership patterns, due to mergers and acquisitions;
- the current process of privatisation of State forestry assets;
- the conflict between the abundance of labour and the steady increase in mechanisation; and
- the high incidence of HIV/AIDS and its potential influence on the industry.

Within the context of globalisation, the South African forest industry needs to remain competitive in its operations in order to compete on the international market. This can only be done by having a greater understanding of the future and how best to prepare for it and influence it, where possible. Due to the high contribution that the Forest Engineering value chain has on the cost structure in forestry, this study could make a significant contribution to the competitiveness of the industry.

1.9 An overview of global forestry

1.9.1 Forest cover

The area of the world's forests, including natural forests and forest plantations, was estimated to be 3 454 million hectares in 1995, or about a quarter of the world's land area (FAO, 1999). About 55 percent of the world's forests are located in developing countries, with the remaining 45 percent located in developed countries (Figure 1.7)

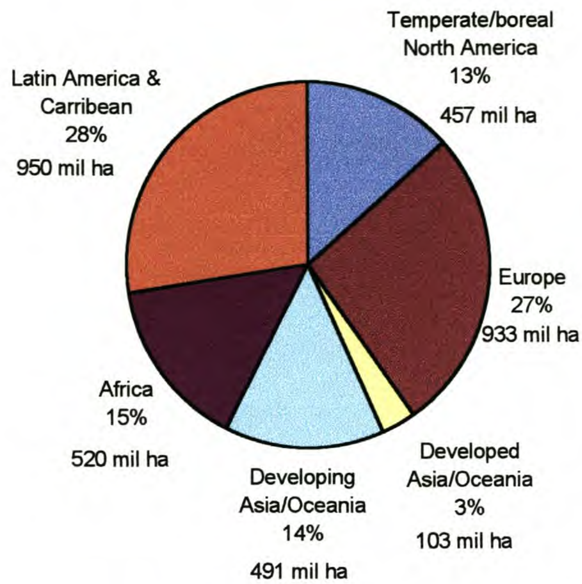


Figure 1.7: Forest areas by main regions in 1995 (FAO, 1999)

The world's forests are almost equally divided between tropical/subtropical forests and temperate/boreal forests. Only about 3 percent of the world's forests are forest plantations. The remaining 97 percent are natural or semi-natural forests.

1.9.2 Change in forest cover

Between 1980 and 1995, the extent of the world's forests (including both natural forests and forest plantations) decreased by some 180 million hectares. There was a net increase of 20 million hectares in developed countries, but a net loss of 200 million hectares in developing nations. The change in forest area by region between 1980 and 1995 is shown in Figure 1.8.

Between 1990 and 1995, there was an estimated net loss of 56.3 million hectares of forests worldwide. This represented a decrease of 65.1 million hectares in developing countries and an increase of 8.8 million hectares in developed countries. Although the global loss of forests was still very high, the figures suggest that the rate of deforestation might be slowing down. The estimated change in natural forest cover in developing countries (which is where most deforestation is taking place) was an annual loss of 13.7 million hectares between 1990 and 1995, compared with 15.5 million hectares per year over the decade 1980-1990 (FAO, 1999).

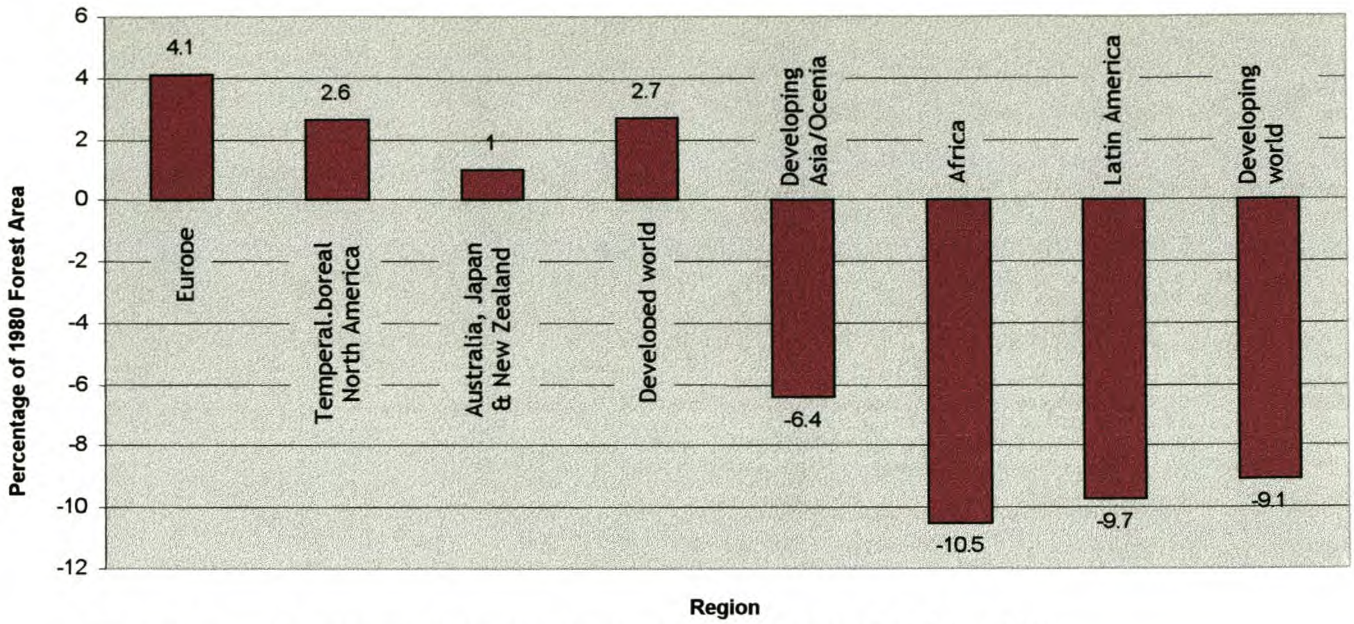


Figure 1.8: *Change in forest area between 1980 and 1995 (FOA, 1999)*

1.9.3 Natural forests

Nearly one-half (1 561 million hectares) of the area of natural forests worldwide (an estimated 3 221 million hectares) is considered to be available for wood supply under current legal and market conditions (i.e. there are no legal restrictions and forest cover is both economically and physically accessible). The figures are summarised in Table 1.1.

Table 1.1: *Natural forests – area available and unavailable for wood supply (FAO, 1998)*

Natural forest classification under the Global Fibre Supply Model	Area (million ha)
Area available for wood supply	**1 563**
Semi-natural	898
Undisturbed by humans	665
Area unavailable for wood supply	**1 657**
Legal restrictions	290
Economic restrictions:	
Physical reasons	256
Transport/infrastructure constraints	365
Other	746
Total area of natural forest	**3 221**

Concerns related to timber harvesting and the need to encourage the use of environmentally sound forest harvesting practices apply to this area. At least 42 percent (665 million hectares) of the area available for wood supply is estimated to be "undisturbed by humans"; three-quarters of this area being located in the Russian Federation.

An additional 365 million hectares of natural forests are currently unavailable for wood supply because of transport or infrastructure constraints, but have potential for commercial timber harvesting, should economic conditions change and government policies encourage commercial development of this resource. Countries will face important choices on how this land can best be used to support national sustainable development. Some of these forests will undoubtedly be cleared for other uses, some may be added to national protected area systems, and some will be managed for commercial timber production. Some will remain too remote, and thus uneconomic, for commercial forestry activities to take place.

The area of natural forest that is currently available for wood production is diminishing because of deforestation and the designation of some forests as strict conservation areas. The Philippines, for instance, has recently banned all logging in "old growth and virgin forests".

In China, a similar ban on timber harvesting in natural forests was imposed in July 1998. Proposals have been made to add about 60 percent of the State-owned natural forests (approximately 25 million hectares) to the country's protected area system, which would have an overall effect of reducing log production from the State forest areas by 43 percent. In Surinam, 1.5 million hectares of natural forest (one-tenth of the country's total land area) were set aside as a Wilderness Nature Reserve in 1998. In April 1998, the Government of Brazil announced its intention to put 25 million hectares of rainforest under protected area status. In addition, Brazil, Cambodia, New Zealand, Sri Lanka, Thailand and the United States, among others, have recently either banned or severely restricted timber harvesting in primary forests.

Other recent developments which may affect the area of natural forests available for wood supply are the restitution of large forest areas to past owners in Eastern

Europe, the devolution and decentralisation of responsibility for forest management (e.g. in the Philippines) and the designation of large areas of public forests for the use of native communities (e.g. in countries in the Amazon basin region, the Philippines and Canada). New owners of small areas of forests or woodlands in many developed countries are increasingly likely to use their forests for aesthetic or recreational purposes rather than for timber production. Changing ownership patterns, in which larger areas of natural forest are divided into smaller, individually owned forest units may, in some cases, make timber production uneconomical. The overall effect is expected to be a reduction in the area of natural forest available for wood supply.

More than 150 countries are participating in regional and eco-regional processes to establish criteria and indicators for SFM. Member countries of the International Tropical Timber Organisation (ITTO), which collectively account for more than 80 percent of the world's tropical forests and more than 90 percent of the global tropical timber trade, have made a commitment that their exports of tropical timber and timber products will originate from sustainably managed forests. The World Bank and WWF have also joined forces in a programme aimed at having 200 million hectares of forests certified as being sustainably managed by the year 2005.

Many wood producing countries will continue to rely on natural forests as their main source of their wood supply, at least for the short-term. Only a few countries currently harvest the majority of their wood from forest plantations and trees from outside forests (FAO, 1999).

1.9.4 Forest plantations

Forest plantations have attracted both considerable positive attention and criticism in recent years. Plantations will become increasingly important sources of industrial wood in the future, thus potentially allowing reduced levels of timber harvesting in natural forests. Some groups such as the World Rainforest Movement, however, oppose them as being unsustainable monocultures unable to provide the multiple goods and services available from natural forests (Carrere and Lohmann, 1996). However, there is in general, an acceptance of plantation forestry being an acceptable practice, as reflected in the New Zealand Forest Accord signed in 1991. Signatures included major environmental groups and industry Associations (Neilson, 1994). There is concern that some natural tropical forests are being cleared and replaced with forest plantations. However, plantations have the potential to meet the increased demand for industrial wood products and thus their indirect role in conserving natural forest resources remains an important fact.

The area of forest plantations in the world has been increasing for the past two decades, and this trend is expected to continue. Vietnam, for example, recently announced plans for the rehabilitation of 5 million hectares of forestland, of which about 3 million hectares would be forest plantations. Other countries with continuing afforestation programmes include Australia, New Zealand, Argentina, Brazil, Chile, China, India, Indonesia, Morocco, Thailand and Uruguay.

Several developed countries (e.g. Sweden) in the temperate and boreal regions have forests of native species that are largely naturally regenerated, but which also rely on supplementary plantings to be undertaken. The difficulty of distinguishing forest plantations from natural forests, or rather the fact that a hybrid of the two prevails in many countries, has made it extremely difficult to obtain exact figures on the area of forest plantations in the developed world.

An estimate, however, is that there are over 60 million ha of forest plantations, of which about 29 million ha are in European countries (including over 17 million ha in the Russian Federation), 13 million ha in the United States, 10 million hectares in Japan, six million ha in South America, 2,5 million ha in Oceania and 1,4 million ha in South Africa.

Forest plantations make up a large proportion of some countries' total forest cover (e.g. 44 percent in Japan and 19 percent in New Zealand). Not all of these plantations have been established for wood supply. In Japan for example, many have been planted for protection functions, such as soil and water conservation, slope stabilisation and wind protection. Table 1.2 shows regional totals of forest plantations established for wood supply in developing countries.

Table 1.2: Forest plantation areas and annual establishment rate in developing countries in 1995 (FAO, 1999)

Region	**Reported areas ('000 ha)**				
	Industrial	**Non-industrial**	**Total**	**Estimated net areas**	**Area established per year**
Africa	3 787	3 025	6 812	5 861	288
Asia and Oceania	31 781	21 216	52 997	40 471	2 330
Latin America	7 826	2 134	9 960	8 898	401
Total	**43 394**	**26 375**	**69 769**	**55 230**	**3 019**

Almost 75 percent of forest plantations are located in Asia and the Pacific region (with 21 million hectares in China and 20 million hectares in India), while about 15 percent are in Latin America and 10 percent in Africa. The reported annual afforestation rate in the tropics and subtropics in 1995 was about 3 million hectares per year.

An estimated 57 percent of the plantation area is planted with hardwood species and 43 percent with softwoods. Various species of pines make up the majority (61 percent) of the softwoods. Eucalypts comprise the largest area of hardwood plantations planted for industrial use (30 percent), followed by Acacias (12 percent) and teak (about 7 percent). Short-rotation plantations of hardwood species have been grown for many years, but until recently there has been little interest in growing valuable hardwood species, such as teak, because of their slow growth and delayed economic returns. Because of the prospect of reduced supplies of high-quality hardwood logs from natural forests, however, a number of countries — Costa Rica, Ghana, India and Malaysia among them — are now investing in plantations of valuable hardwood species, especially teak.

Utilisation of wood and fibre from species not traditionally considered forest crops — in particular rubber, coconut and oil palm — has continued to increase. Coconut and oil-palm stems and the branches of rubber wood are used in various forms of reconstituted wood, and rubber wood stems are used for lumber. About 80 percent of the furniture currently manufactured in Malaysia is made from rubber wood; this industry was valued at approximately US$750 million in 1997. Furniture is also manufactured from rubber wood in Thailand, and this industry is being developed in

China, India, Indonesia and Vietnam. Rubber wood has in fact become so valuable that the Rubber Research Institute of Malaysia is now breeding dual-purpose latex/timber clones, which have recently been released for commercial planting (FAO, 1999).

Forest plantations established for industrial wood supply can help compensate for an anticipated reduction in production from natural forests because of deforestation or increased areas being set aside for conservation or other reasons. For example, over 25 000 ha of high-yielding hybrid poplar plantations were established in the north-western United States between 1992 and 1997 in response to both increased demand for poplar wood for oriented strand board (OSB) and a decreased supply from public forests (USDA Forest Service, 1996). There is also a perception that the establishment of a sufficient area of forest plantations may reduce logging pressure on natural forests by providing an alternative source of wood supply. One of three objectives of the forest plantations programme in Malaysia is to reduce pressure on natural forests through higher timber outputs from concentrated plantation forests. A similar strategy has also been applied in New Zealand.

No accurate global figures are available for the current output of timber from forest plantations, but the potential growth of industrial wood from forest plantations in developing countries has been estimated at about 5 percent of the increment of natural forests in 1995. In some countries, however, plantation production already makes up a significant proportion of the industrial wood supply. For example, 99 percent of New Zealand's industrial roundwood in 1997 was grown in plantations, 84 percent of Chile's, 62 percent of Brazil's, 50 percent of Zambia's and 100 percent of South Africa's.

Projections of the future contribution of forest plantations to wood supply are based on various assumptions, the main one being the rate of afforestation. Considering today's rates of deforestation and afforestation, it is estimated that by 2010 the potential increment from forest plantations will be about 40 percent of that from natural forests in Asia, Oceania and Latin America and about 15 percent in Africa.

Gains in the productivity of forest plantations continue to be made through improved management, tree breeding and tree improvement. Simple selection, particularly of provenances, may give results nearly as dramatic as and often more resilient to external influences than intensive tree breeding. Recent advances in biotechnology are increasingly being applied in the forestry sector, resulting in improved yields. For example, many of the environmental and social issues surrounding forest plantations are related to the way that they are established — blocks of trees of the same age and same species planted in straight lines with regular spacing. Criticism of monoculture has increased interest in using more than one species in plantations. The potential benefits of mixed-species plantations include reduced risk of diseases, improved nutrient cycling in forest soils, reduced risk of fire damage when suitable fire resistant species are used, increased habitat diversity for native plant and animal species, increased market security through species and product diversification and improved visual and aesthetic characteristics. However, information on the establishment and management of such mixed-species plantations is limited.

The availability of land suitable for forest plantations is of growing concern. Private enterprise is increasingly conscious of environmental and social issues related to the establishment of large blocks of trees. The clearing of forests for plantations is reported to have ceased in Chile, Argentina and Brazil, although it is still continuing in Indonesia and some other countries. The limitation of land has led to the growing of trees for industrial roundwood production on land outside forests, such as farmland, where trees are either planted as small blocks or integrated with agriculture in agro-forestry systems. In Pakistan, for example, 45 percent of respondents to a survey on farm trees grew trees for timber production on irrigated farmland, which made a significant contribution to wood supplies (Leach, 1993).
"Outgrower" schemes encourage farmers to grow trees on their own land for sale to processing companies. There are many such schemes, for example, *Populus deltoides* grown for peeler logs in India, *Albizzia falcataria* grown for pulpwood in the Philippines and *Acacia mearnsii* grown for bark and eucalypts for pulp in South Africa. Under these schemes, outgrowers usually receive loans, improved planting stock, technical advice and a guaranteed price for this product (FAO, 1999).

1.9.5 The role of forests in mitigating global climate change

The concentrations of greenhouse gases in the Earth's atmosphere have increased since the onset of the industrial revolution, largely because of human activities such as fossil fuel combustion and land use conversion. The concentration of carbon dioxide (CO_2,), the main greenhouse gas emitted by human activities, increased by nearly 80 parts per million by volume (ppmv) between 1880 and 1994, after having fluctuated within a range of about 10 ppmv over the previous 1 000 years.

Forests can serve as reservoirs, sinks and sources of greenhouse gases and thus have a significant role in moderating the net flux of greenhouse gases between the land and the atmosphere. Forests act as reservoirs by storing carbon in biomass and soils. They are sinks of carbon when their area or productivity is increased, resulting in the uptake of atmospheric CO_2. Conversely, they are sources of carbon when the burning and decay of biomass and disturbance of soil result in emissions of CO_2 and other greenhouse gases. Net CO_2 emissions from changes in land use (primarily deforestation occurring mainly in tropical areas) currently contribute about 20 percent of global anthropogenic CO_2, emissions (Schimel, Alves, Enting, Heimann, Joos, Raynaud and Wigley, 1996).

Various practices related to the forest sector can be grouped according to their roles in helping to slow the accumulation of CO_2 in the atmosphere.

- *Conservation management.* Existing stocks of carbon in forests can be maintained through forest preservation, sustainable harvesting and increased productivity on existing agricultural land which can reduce the rate of deforestation and forest degradation and prevent associated CO_2 emissions.
- *Storage management.* Activities that increase carbon storage in forests and forest products include increasing the forest area, increasing the forest carbon stored per unit of area through silvicultural measures (e.g. longer rotations, increased tree stocking densities, reduced impact logging) and extending the time over which harvested wood remains in use. These activities lead to a net uptake of CO_2 from the atmosphere.
- *Substitution management.* Substituting fuelwood from sustainable managed forests for fossil fuels produces a CO_2 benefit when the emissions from biomass combustion are offset by biomass growth, and emissions from fossil fuel combustion are avoided. Substituting more energy-demanding products, such as steel or concrete, with wood products can reduce the CO_2 emissions from the product manufacturing industries.

In the case of both conservation and storage management projects, the permanence of the CO_2 benefits depends on the protection of carbon stocks against natural threats (e.g. forest fires, storms and diseases) and human threats (e.g. clearance of the forest and conversion to another land use). For example, the CO_2 benefits of forest conservation may be negated if the forest is eventually burnt or over-harvested, or if decreased wood harvesting on one area results in more harvesting elsewhere.

1.10 An overview of forestry in South Africa

1.10.1 Development of the plantation industry

South African forests gained real significance in 1652 with the arrival of Dutch settlers at the Cape and again in 1820 when English settlers arrived in the Eastern Cape and Natal. The importance of woodlands increased significantly with the colonisation of the interior after 1836.

The early history of the closed canopy forests was one of uncontrolled exploitation and devastation. It was not until the early 1700's that attempts were made to protect the forests of the south-western Cape and not until the mid 1800's in the Eastern Cape. The first Forest Act, for the Cape Colony, was promulgated in 1888 after the appointment of the first formally trained forest officer in 1880. Prior to Union in 1910, there were four Provincial Forest Services, with the most active being located in the Cape Colony.

Though Governor Van der Stel had established a plantation of oaks at Newlands in 1670, it was not until 1875 that the first real planting of exotic timber species began, this being greatly spurred on by the demand for fuelwood for the fledgling railways. Black wattle had been introduced from Australia in 1864 and by 1880 was recognised as a superior vegetable tanning material. Plantings expanded from the early 1900's. By 1910 an area of 60 000 ha had been commercially planted to wattle.

After the formation of the Union of South Africa in 1910, a Chief Conservator of Forests was appointed and the Provincial services were brought under Federal control. The early Union Forestry Service pursued a protectionist strategy towards the remaining indigenous closed canopy forests, while moving forward with the establishment of man-made timber plantations. During these early years, many small plantations were established along the eastern seaboard, but especially in the eastern Cape. In 1938 it was recorded that 150 000 ha of "commercial" timber plantations, and the first sawmill, had been established by the State. Meanwhile, the private planted area had increased to 370 000 ha, including 220 000 ha under wattle.

In the years up to the Second World War, forestry was almost exclusively run by the State and was strongly associated with agriculture, the one exception being the wattle industry in KwaZulu Natal, which was largely private. After the Second World War, an independent Department of Forestry was established by the State.

The Second World War brought into focus South Africa's geographic vulnerability in respect to timber supplies. In the early 1950's the State expanded the timber resources, especially by encouraging the private sector to plant trees. This brought an immense surge in afforestation. By 1960 the total planted area had reached 981 640 ha, of which 720 320 ha, including 355 000 ha wattle, was privately owned (Owen and Van der Zel, 2000).

By 1961 the planted area of State plantations comprised some 273 568 hectares, of which approximately 105 218 hectares were located in the Transvaal (i.e. the northern and north-eastern parts of the country), approximately 24 280 hectares in the south-east, with the balance along the southern coastal regions from Durban to Cape Town.

A 35-year rotation was commonly applied to exotic conifer species in South African plantations on average sites. Table 1.3 shows the distribution of age classes in the softwood planted area (1961), which reflects an average age of 12 years (Zaremba, 1976).

Table: 1. 3 Age distribution of State and private plantation areas in 1961 (Zaremba, 1976)

Age class	Total coniferous area	Percentage
Years	Hectares	
0 – 5	122 242	27,4
6 – 10	135 700	30,5
11 – 15	80 986	18,2
16 – 20	23 192	5,2
21 and older	83 272	18,7
TOTAL	**445 392**	**100**

The plantations consisted primarily of pine species, the following being the most prevalent:

- Fast-growing species: *Pinus patula, Pinus radiata.*
- Medium-fast-growing species: *Pinus elliottii, Pinus taeda, Pinus pinaster* (Portuguese strain).
- Slow-growing species: *Pinus pinaster, Pinus palustris, Pinus canariensis.* (Zaremba, 1976).

By 1975 the total planted area had reached just over 1.1 million hectare, of which 769 000 ha was privately owned. Wattle bark demand on the international market peaked in 1962 and as the market declined so large areas of wattle were converted to eucalypts or agricultural crops, such as sugar (Owen and van der Zel, 2000). In 1975 the total planted area was divided into 198 management units ranging in size from 10 ha to over 4 000 ha, with a size distribution as shown in Table 1.4.

Table: 1.4: Plantation size distribution: 1975 (Zaremba, 1976)

Size (hectares)	No. of plantations
10 – 40	3
41 – 80	4
81 – 200	10
201 – 400	29
401 – 2000	89
2 001 – 4000	57
4 000 and over	6
TOTAL	**198**

Substantial groups of plantations forming planted blocks of considerable size were only to be found in the old Eastern Transvaal and Zululand, and to a limited extent in Natal and the Northern Transvaal, but for the remaining areas, large gaps often occurred between groups of plantations and even between individual plantations themselves. This scattered location of the planted area severely limited effective planning, management and the extensive use of mechanical equipment (Zaremba,1976).

By 1985 the Department of Forestry controlled 1,6 million ha of land, of which 263 000 ha was under commercial timber plantations. Due to Government policy, the eight independent and self-governing administrations controlled a further 350 000 ha of land of which more than 150 000 ha were under plantations. The area under private ownership was 800 000 ha. (In 1986 one million ha of unplanted State Forest mountain catchment area, along with a small plantation area, was transferred from the Department of Forestry to the Provincial Nature Conservation authorities).

In 1992, the Government of the RSA decided to commercialise its timber production activities. The South African Forestry Company Limited (SAFCOL) took over approximately 500 000 ha of State Forest land, of which 263 000 ha was planted to timber plantations. The State retained 86 000 ha of land, most of which was under closed canopy natural forest, while the independent and self-governing administrations had a commercial and community plantation area in excess of 160 000 ha. The official total planted public plantation area was 418 023 ha. The plantation area under private ownership was 952 870 ha, including a wattle area of 124 117 ha.

After the first fully democratic election in 1994, the plantations of the former independent and self-governing administrations returned to the control of the Department of Water Affairs and Forestry (DWAF). This was intended to be a temporary measure as it was the intention to privatise the commercial timber interests of both SAFCOL and the Department (Owen and van der Zel, 2000).

Historically, attention was given to conserving the remnant closed canopy forests, while developing a thriving industry based on man-made timber plantation resources. These plantations presently cover slightly less than 1,4% of South Africa. Minimal attention was given to the natural woodlands, except in areas primarily conserved for the protection of fauna (Owen and van der Zel, 2000).

1.10.2 Geography and climate

South Africa forms the southern most part of the African continent and lies almost entirely within the Southern Temperate zone between 22° and 35° latitude. The country has a surface area of 1 124 017 km^2, that is five times the size of Great Britain and larger than the combined areas of Germany, Italy, the Netherlands and Belgium. High escarpments rise steeply in the east and southeast, sloping gradually to the west coast and encircling a vast interior plateau.

South Africa is a country of low mean annual rainfall. As a result, most of the natural vegetation is non-woody, with natural forests consisting of a narrow broken belt of closed canopy forest running along the southern and eastern seaboards and open canopy savannah woodlands in the north-eastern interior of the country. Compared with today's world mean in excess of 30%, South Africa's natural closed canopy forest covers only roughly 0,5% and savannah woodlands roughly 19,0% of the total land area.

The largest portion of the country receives summer rainfall. A relatively small region in the South-Western Cape has a Mediterranean climate, while a strip along the south coast is located in a constant rainfall region.

In general, rainfall decreases from the east to the west. Along the east coast the rainfall exceeds 1 000 mm and decreases gradually to less than 125 mm in the desert region. On the central plateau, the rainfall varies between 375 mm and 750 mm annually. About a quarter of the country has a mean annual rainfall of more than 625 mm (Department of Foreign Affairs, 1984).

The overall climate can be classified as being temperate and all forestry operations can be continued throughout the year. Humidity is moderate, except for the hot, humid plains of Zululand. Temperatures vary from 2° to 38° Celsius for most of the area. The rainy seasons do not affect harvesting operations to any serious degree and these can continue uninterrupted throughout the year with the exception of brief periods when heavy downpours of rain occur.

Figure 1.9 shows a map of the forestry areas in South Africa. Note the concentration of plantations in the south and east of the country, due to the higher rainfall patterns experienced in those areas.

Topography varies considerably throughout the planted area and ranges from flat to undulating with occasional steep mountain slopes. Virtually the whole area, with a few exceptions such as excessively steep, inaccessible areas and marshes, is nevertheless accessible for extraction with ground-based equipment. The most difficult, rocky, inaccessible areas produce poor timber yields which are costly to extract. Terrain is generally firm throughout the country with the exception of limited areas within Zululand where marshes occur in places. The surface is generally smooth and free from undue obstructions, but stony ground, with scattered boulders and rocky outcrops, sometimes occur on steep mountain slopes (Zaremba, 1976).

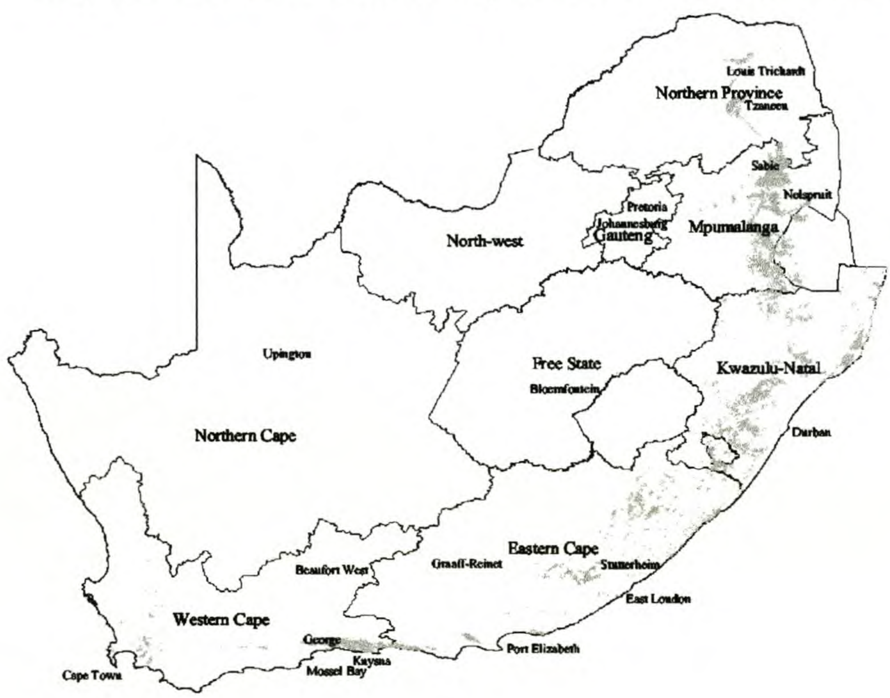


Figure 1.9: Map showing location of forestry plantations in South Africa and Swaziland (Strydom, 1999)

Warkotsch, Brink and Zietsman (1989) conducted a study on the slope classes prevalent in the South African forestry areas, the results of which are given in Table 1.5.

Table 1.5: Slope classification of South African plantation areas (Warkotsch, Brink and Zietsman, 1989)

Species	Slope (Percent)									
	< 20		20,01 – 35		35,01 – 60		> 60		Total	
	Area									
	ha	%	ha	%	ha	%	ha	%	ha	%
	Mpumalanga									
Pine	247 625	66	83 400	22	40 519	11	3 793	1,0	375 337	100
Eucalypt	242 956	81	39 244	13	15 175	5	1 056	0,4	298 431	100
Wattle	42 406	98	625	1	187	1	6	0	43 224	100
Total	532 897	74	123 269	17	55 881	7	4 855	1,0	716 992	100
	KwaZulu Natal									
Pine	107 037	82	19 444	15	3 525	3	81	0,1	130 087	100
Eucalypt	128 881	88	14 862	10	2 456	2	63	0	146 268	100
Wattle	86 900	88	10 363	11	1 462	2	125	0,1	98 850	100
Total	322 818	86	44 669	12	7 443	2	275	0,1	375 205	100
	Cape									
Pine	36 744	52	20 837	30	11 156	16	1 794	2,5	70 531	100
Eucalypt	8 825	82	1 544	14	381	3	6	0,1	10 756	100
Wattle	13 319	70	4 438	23	1 256	7	63	0,3	19 076	100
Total	58 888	59	26 819	27	12 793	13	1 863	2,0	100 363	100
	Total R.S.A.									
Pine	391 406	68	123 694	21	55 206	1,0	5 669	1,0	575 975	100
Eucalypt	380 663	84	55 650	12	18 013	0,2	1 131	0,2	455 457	100
Wattle	142 625	89	15 425	9	2 906	0,1	193	0,1	161 149	100
Total	914 694	77	194 769	16	76 125	0,6	6 993	0,6	1 192 581	100

The results of the Table indicate the following with regard to the application of harvesting systems:

- By slope category, 77% of the total area is on flat terrain (<20%), 16% on medium slope (20,01% - 35,0%), 6% on steep terrain (35,01% - 60,0%) and 1% on very steep terrain (>60%).
- This means that wheeled extraction is suitable for use on 93% of the area, extraction by chute on 22% and cable yarding on 7% of the area.
- By species, in the case of pine, 89% is suited to wheeled extraction, 31% for chute extraction and 11% for cable yarding. In the case of eucalypt spp., 96% is suited to wheeled extraction, 16% to chute extraction and 4% to cable yarding. The respective percentages for wattle are 98%, 11% and 2%.

1.10.3 Organisation of the South African forest industry

The private forestry owners consist of three or four large corporate companies, several smaller corporate companies, tree growing farmers and a rising number of individual small timber growers. These parties operate in terms of their management policies but are generally members of one or other of the following Associations (Owen and van der Zel, 2000):

- Forest Owners Association
- Southern African Timber Growers Association
- South African Wattle Growers Union
- South African Lumber Millers Association
- South African Wood Preservers Association
- Paper Manufacturers Association of South Africa

In terms of Section 33 of the National Forests Act, 1998 (Act No 84 of 1998) a National Forestry Advisory Council has been established to advise the Minister of Forestry "on any matter related to forestry in the Republic" (Owen and van der Zel, 2000).

Figure 1.10 illustrates that companies own the majority of plantation holdings.

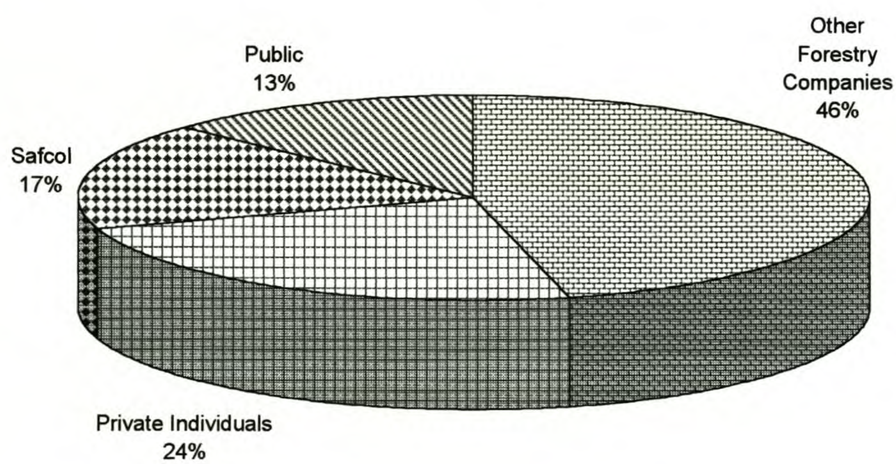


Figure 1.10: Plantation holdings (1996/97) (FOA, 1997)

Table 1.6 gives a breakdown of the species distribution by ownership.

Table 1.6: Plantation area by species/ownership (FOA, 1997)

Species	Ownership 1996/97			Percent privately owned (%)	Percent publicly owned (%)
	Private (ha)	Public (ha)	Total (ha)		
Softwood	432 992	364 618	797 610	54	46
E.grandis	386 295	55 099	441 394	88	13
Other gum	134 507	22 063	156 570	86	14
Wattle	104 000	8 029	112 029	93	7
Other hardwood	4 803	5 732	10 535	47	54
Total	1 062 597	455 241	1 518 138	70	30

1.11 Conclusion

This Chapter has given an overview of the objective of the study and the need to be able to forecast the systems in the Forest Engineering value chain. It was also necessary to give an overview of global forestry and the context in which the South African forest industry operates within this global framework.

With this as background, the developments in the Forest Engineering environment are given in Chapter 2, both globally and locally. The past and future global trends are based on a literature study, while the South African developments are derived from both a literature study, as well as a survey conducted in the industry, referred to as the Forest Technical Survey (FTS). With these developments as background, it is possible to identify the key variables required to forecast the systems in the Forest Engineering value chain.

2. DEVELOPMENTS IN THE FOREST ENGINEERING ENVIRONMENT

2.1 Introduction

Without a sound understanding of the past, the future cannot be explored. Chapter 2 focuses on the past Forest Engineering developments, both globally and in South Africa. Two distinct and diverging developments took place in harvesting systems. North America is the birthplace of tree-length (TL) systems, with the majority of the equipment used in TL systems being developed and manufactured in the USA and Canada. On the other hand, the Scandinavian countries, primarily Sweden and Finland, developed machines working in mechanised cut-to-length (CTLM) systems. A tree-length system primarily combines a feller buncher and a grapple skidder, while a CTLM system consists of a harvester and forwarder combination. An overview of these two development patterns in North America and Scandinavia are thus given.

The chapter then moves to the developments in South Africa and includes a comprehensive survey, which was conducted in 1997. The survey forms the point of departure for the forecasting exercise completed in Chapter 5. It is a comprehensive exercise, which includes all forestry units in excess of 200 ha in South Africa.

The chapter is concluded with a literature overview of future Forest Engineering developments globally. This is necessary, to gain a broad overview of existing literature on the subject.

2.2 Global developments

2.2.1 The development of harvesting technologies

2.2.1.1 North America

The North American forests are vast, constituting some 457 million ha of land (FAO, 1999). Productive forests cover 25% of the total land area of Canada.

Harvesting during the first half of the century was very labour intensive, with axes, bow saws and crosscut saws being used exclusively. This resulted in the use of a short wood system, where stacked logs were extracted to landing with the use of horses. In the mid 1920's crawler tractors were introduced. Throughout the winter months timber was extracted by crawler- or horse drawn sleds to rivers. Once at the riverside, the logs were floated to the mills on the spring flood (Guimier, 1991).

The end of World War II signalled the advent of rapid mechanisation. Two breakthroughs are particularly relevant – the chainsaw and the wheeled skidder.

Although the chainsaw was actually invented in 1850, two technological breakthroughs emanating from World War II contributed to its large-scale use. These were the use of light metal technology and the development of a small, air-cooled engine. Prior to the War, an average chainsaw weighed 40kg. In the early 1950's this dropped to 15kg and by 1960 the average weight was a mere nine kg. Today, a chainsaw weighs between four and seven kg, depending on the application. By 1960, the chainsaw had fully replaced traditional methods of manual felling.

Farm tractors were originally used, to a limited extent, for extraction but were found to lack the mobility and mechanical reliability required in the rugged forest environment. A breakthrough was made with the advent of the articulated wheeled skidder. Simultaneously, improved transmission of hydraulic power and the knuckle boom concept were introduced. The combination of these innovations triggered the full-scale mechanisation of timber harvesting (Heidersdorf, 1991). The result thereof was a rapid shift to tree-length harvesting systems, where the tree was felled, debranched and topped infield, and then extracted to a landing by skidder.

The first feller bunchers were introduced in the late 1960's. They consisted of tracked excavator carriers, fitted with shear heads. These heads could fell only one tree at a time, making them less popular for the felling of small diameter trees. In the late 1970's, accumulator arms were introduced, leading to significant productivity gains.

The first circular saw heads were manufactured in the late 1970's. These heads quickly gained market share at the expense of shear technology because of improved productivity and a consequent reduction in butt damage.

Being less sensitive to tree size, skidding machines have not undergone the same degree of change as felling machines have. Skidders became larger, as the feller bunchers' ability to prepare larger bundles and the grapple skidder was introduced to compliment the superior stacking features of the feller buncher (Brink, 2000).

Debranching is still seen as a costly operation, primarily because of the trade-off between debranching quality and high production multi-stem capabilities. Tree-length systems are mostly complimented by stroke boom delimbers, which were developed in the mid 1970's.

Since the mid 1980's, there has been a re-introduction of the short wood system, most profoundly in eastern Canada, using CTLM machines originating in the Scandinavian countries. By 1990 there were over 60 such systems (harvester/forwarder) operating in eastern Canada alone. As these machines are being adapted to North American conditions, it is becoming more common to use Scandinavian harvester heads fitted to North American carriers (Guimer, 1991; Brink and Kellogg, 1991).

Even though TL systems are still dominant in North America today, the trend over the last 10 years has been more towards CTLM machines, primarily because of the lower environmental impacts and higher fibre recovery of CTLM systems (Heidersdorf, 1991). Figures 2.1 and 2.2 depict the cutting heads and carriers that were commonly used in North America in the 1980's and 1990's (Brink and Kellogg, 1991).

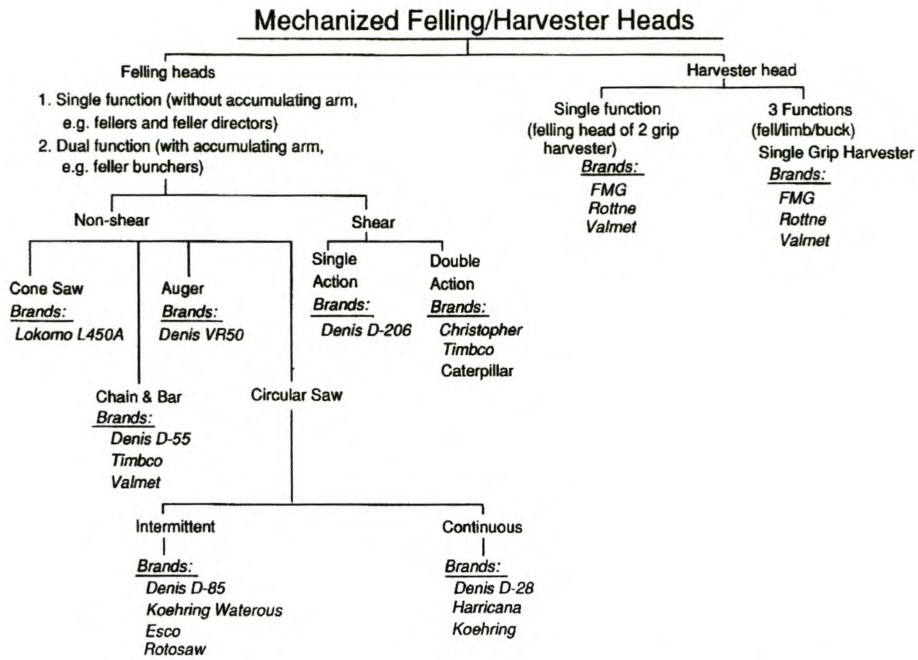


Figure 2.1: Categorisation of felling head types (Brink and Kellogg, 1991)

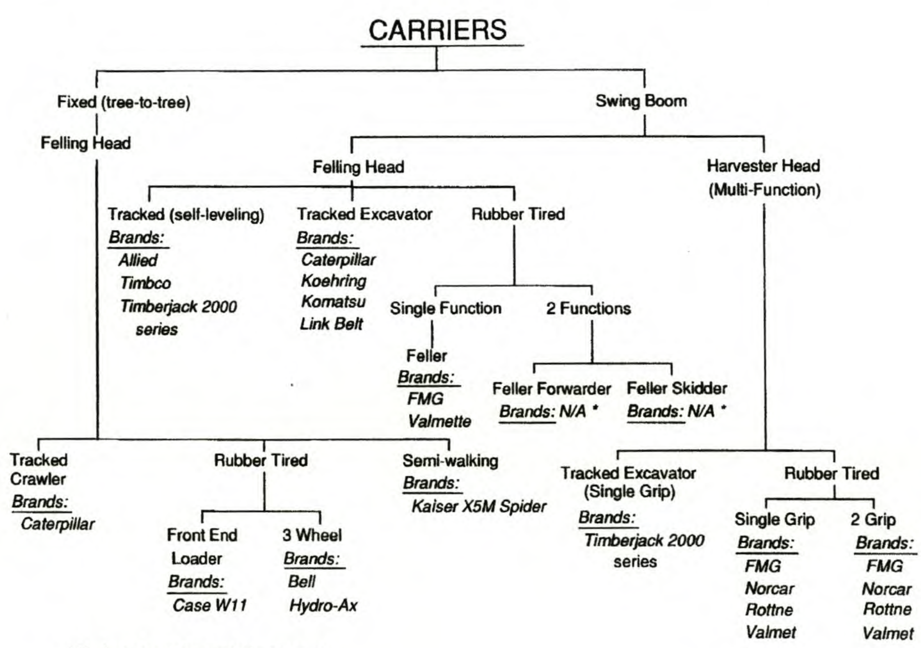


Figure 2.2: Categorisation of carrier types (Brink and Kellogg, 1991)

2.2.1.2 Scandinavia

The development of timber harvesting technology in Sweden is a representative case study of developments in Scandinavia. Sweden is a country of forests, with about 60% of its land area afforested. While the forests are such a valuable national asset, forestry has a long history, covering well over a hundred years. Ever since the latter part of the 19th century the forest sector has been of prime importance to the nation's economy. At present this industry alone provides about 50% of the national net export revenue and forest industry products equal 17% of the total export value.

In spite of the enormous quantities of timber extracted throughout the decades, affording a significant contribution to Sweden's prosperity, the forests of today contain almost twice as much wood as they did at the beginning of the last century.

After the privatisation of the public forests some years ago, only 12% of the 23,5 million hectares of productive forestland is now owned by public interests. Companies own a mere 5,38% of the total productive forest area and 50% is owned by some 250 000 private owners. In Finland, 62 % of the forestland is owned by some 440 000 private forest owners, with an average forest holding of about 26 ha. The State owns 25% of the forestland, large companies 8 %, and others - including municipalities, parishes, common forest owners and other bodies – 5% (FAO, 1999).

Sweden supports the global move of greater social and environmental awareness in the management of forest resources. A Forestry Act, promulgated in 1994, emphasises ecological sustainability, and environmental goals, such as the preservation of biodiversity, are given equal importance to goals regarding timber production (Fryk, 1997).

It is essential for Scandinavia's economy that the forest industry remains competitive on the international market. The cost of wood is the largest component in the total costs of the total forestry value chain. Forest Engineering operations therefore need to be carried out efficiently to minimise cost and for the value-optimised utilisation of the timber to occur. Without profitability it is also questionable if the high environmental requirements can be satisfied.

The most important factor in Swedish forestry has been the mechanisation of forestry operations. This process has largely contributed to the seven-fold increase in average productivity, expressed in terms of m^3/manday, since the early 1960's, as shown in Figure 2.3. Its effect on the labour force was dramatic. Some 40 years ago there were 150 000 fully employed workers in Swedish forestry, while in 1997 that number had dropped to less than 25 000. Factors that have contributed to the continuous increase in productivity are:

- mechanisation of operations;
- improved planning and control systems;
- better trained personnel;
- reduction of personnel; and
- increased use of contractors (Bergström and Carlsson, 1997; Ericson, 1993; Fryk, 1997).

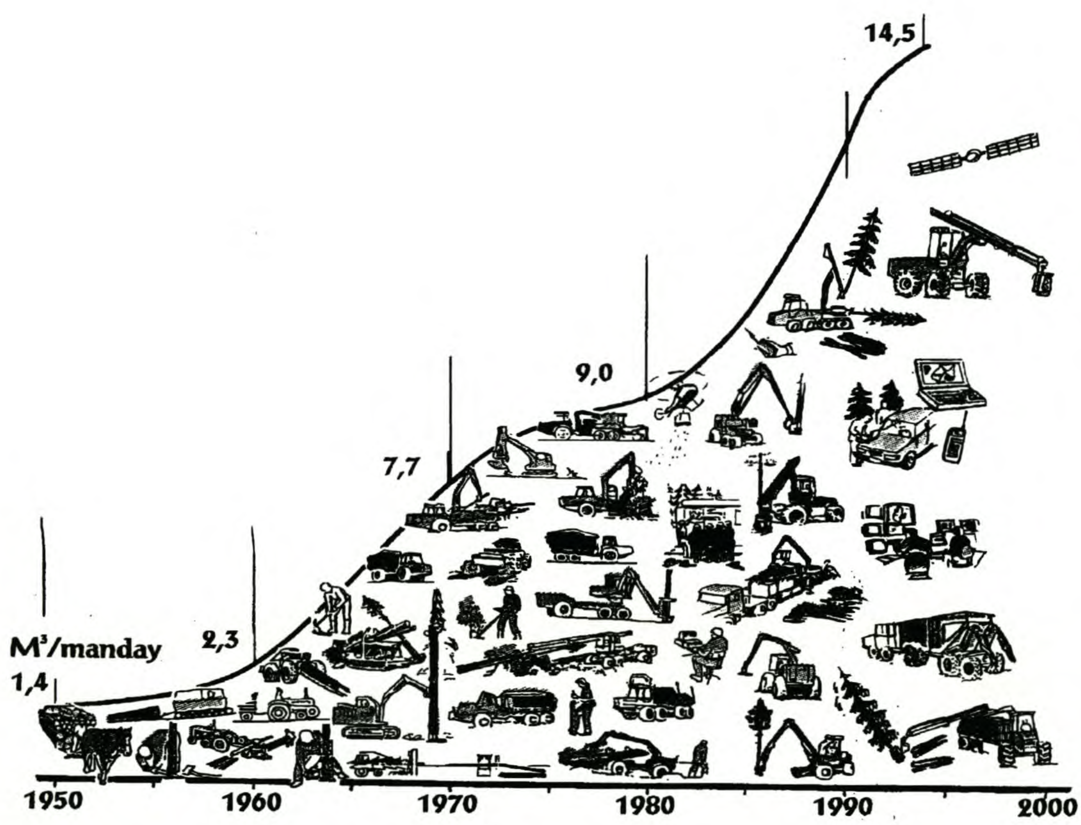


Figure 2.3: Increase in productivity because of harvesting developments in Swedish forestry (Norin, 1997)

Mechanised cut-to-length (CTLM) systems predominate in Sweden with, the level of mechanisation being close to 100%. Almost all thinning operations are carried out by single-grip harvesters, which are rapidly substituting two-grip harvesters in final fellings (Brunberg, 1997; Thor, 1997).

Brunberg (1997) illustrates the continuous increase in mechanisation on both thinning and clearfelling, as depicted in Figure 2.4.

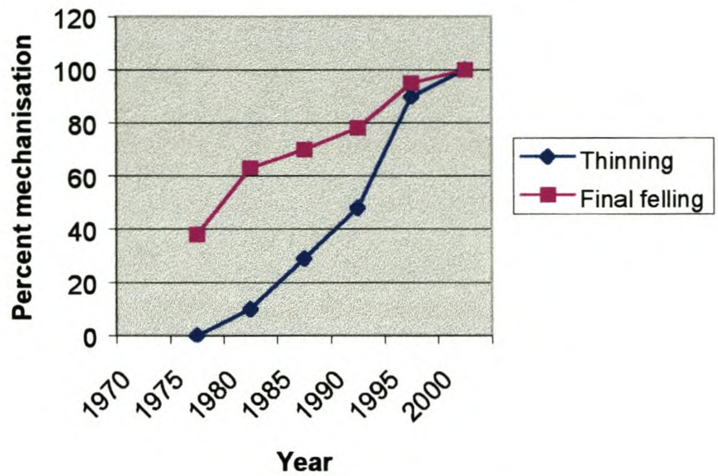


Figure 2.4: Mechanisation trends (1970-1996) (Brunberg, 1997)

The development of mechanisation in thinnings and clearfellings are illustrated in Figures 2.5 and 2.6 respectively.

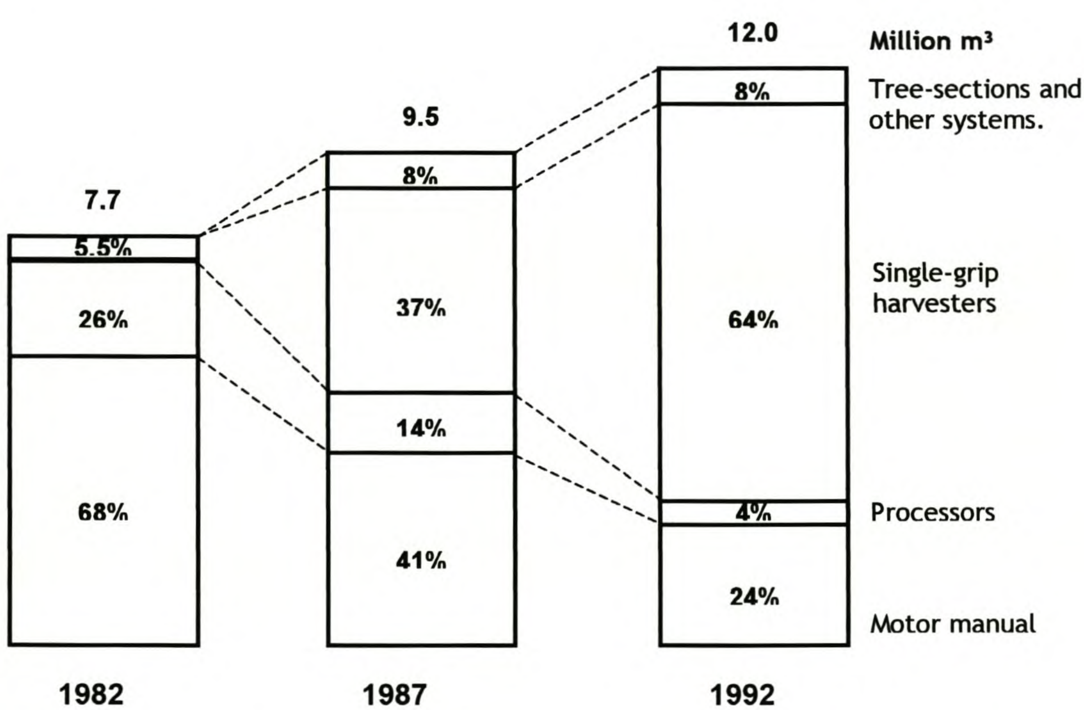


Figure 2.5: Development of mechanisation in thinnings (Frohm,1993)

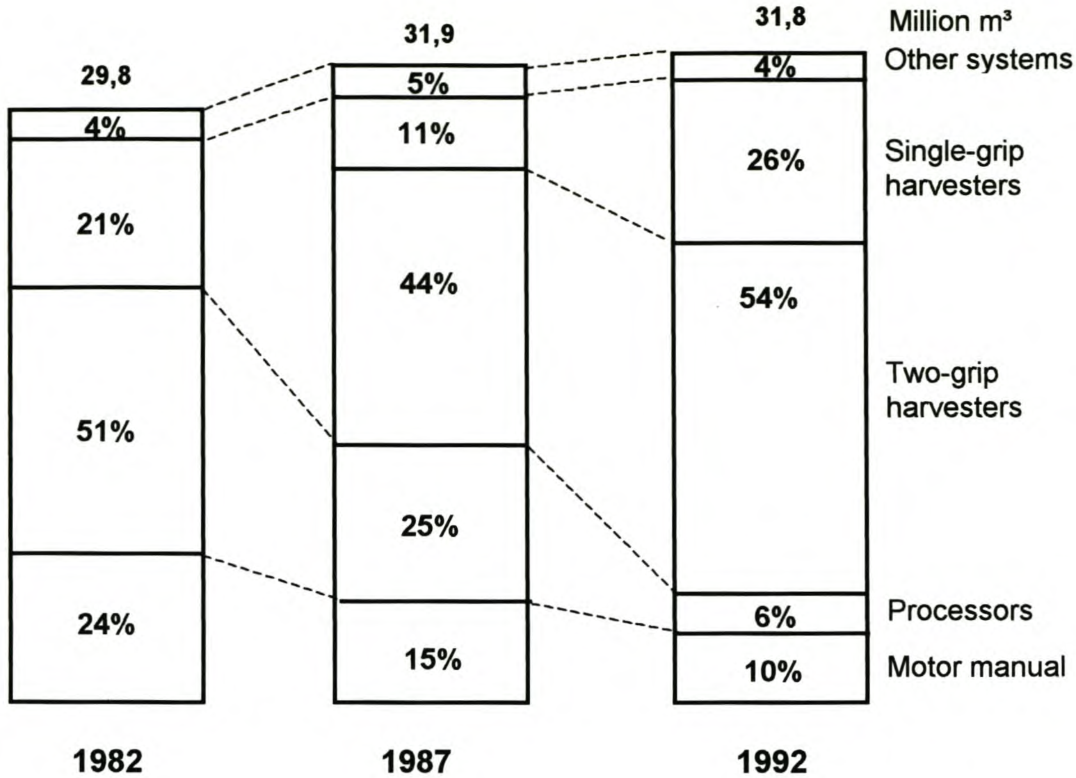


Figure 2.6: Development of mechanisation in clearfellings (Frohm,1993)

The techniques used today are advanced and technically sophisticated, which requires highly skilled and competent operators. Forestry, a complex business in itself, is performed in lean decentralised organisations, with a focus on the education and training of its human resources (Fryk,1997).

The developments described above reflect the birth, development and consolidation of CTLM harvesting technology. Scandinavia has laid the foundation for CTLM technology and its complete harvesting system is moulded around CTLM. Prominent machine manufacturers such as FMG, Valmet, Skogsjan and Loglift originated in Scandinavia and today form an integrated segment of the global machine manufacturers' product range. With Scandinavia being the home of CTLM, the specific development of improved accuracy in the crosscutting function by harvesters has also received continued attention (Sondell, 1997).

2.2.2 The globalisation of the forestry machine market

Porter (1990) described the clustering phenomenon, which results in the grouping of certain industries in a geographic area or country. Within each broad sector, internationally successful industries are grouped into primary goods, machinery used in making them and specialised inputs to the goods and services associated with the goods or their production. This leads to the development of national clusters. At each vertical stage, successful industries are grouped into sub-categories most closely related by end use, in order to further the nature of clustering. As Porter (1990) puts it: "Nations succeed not in isolated industries, however, but in clusters of industries connected through vertical and horizontal relationships". A nation's economy contains a mix of clusters, whose make-up and sources of competitive advantage reflect the state of the economy's development.

Based on the above theory, it is obvious to turn to countries that have an abundance of forests to identify where the competitive advantage lies in timber harvesting machinery manufacture. In the developed world the major forestry areas lie in North America and Scandinavia. Both these geographic regions have had a long history in logging and the concurrent development and improvement of the means to harvest trees cost effectively. This led to the development of clusters of machine manufacturers (mainly small manufacturers) in countries such as the USA, Canada, Sweden and Finland. Today, in excess of 70% of all ground based harvesting machines are produced in these four countries (Shackleton, 2001).

The pattern of international competition differs markedly from industry to industry. Globalisation of industries takes place where a firm's competitive position in one nation significantly affects its position in other nations. Firms combine advantages created at their home base with others that result from a presence in many nations. Rivals therefore compete against each other on a truly global basis, drawing on competitive advantages that grow out of their entire network of global activities. The global industries and firms are compelled to compete internationally in order to achieve or sustain a competitive advantage (Porter, 1990; Pearce and Robinson, 2000). Smith (1998) confirms that globalisation will affect the forestry sector in the future.

With the globalisation of world trade over the last decade, there has been significant merging of companies in similar industries across the world. This has been no different in the forest machinery industry. Forestry equipment suppliers and manufacturers have been rationalised into a few dominant suppliers over the last decade. Some examples of recent mergers and acquisitions are:

1997	Waratah (New Zealand) bought by Timberjack (Canada)
1998	Rosin Harvester head (Australia) bought by Timbco (USA)
1998	30% share of Bell Equipment (RSA) bought by John Deere (USA)
1999	Madill Corporation (USA) bought Thunderbird (USA)
1999	Timberjack (Canada) bought by John Deere (USA)
1999	Skogsjan (Sweden) bought by Caterpillar (USA)
1999	Logtek (USA) bought by Blount (USA)
2000	Timbco (USA) tracked manufacturing rights bought by Partek (Finland) (Brink, 2000).

Although this is not a new phenomenon (e.g. Lokomo and OSA were purchased by FMG in the 1980's), the pace of mergers and acquisitions is increasing. The trend, however, is not unique to forestry equipment suppliers, as demonstrated in the motor industry, the banking industry and the oil industry over recent years. The implication of the above is that the larger machine manufacturers, with greater resources at their disposal, will capitalise and expand on technological advancements on equipment. As with motor vehicles, machines produced for forestry will be generic regarding high technological levels, thereby making repairs and maintenance a specialised function. Simpler local machines will find it increasingly difficult to compete favourably on cost and productivity with the large machine suppliers. The consequence is that a few established global machine suppliers will dominate the South African forestry market. South Africa would therefore primarily be a consumer of machine technology, as opposed to a producer.

2.2.3 Globalisation of the pulpwood market

As with the forest machines market, acquisitions have been rife amongst forest companies. Morkel (2001) summarised recent acquisitions, as depicted in Table 2.1:

Table 2.1: Major mergers and acquisitions of forestry companies (Morkel, 2001)

Date	Company Sold	New Owner
May-97	James River Corporation & Fort Howard	Fort James
Nov-98	Jefferson Smurfit Corporation & Stone Container	Smurfit-Stone Container Corporation
Dec-98	Stora & Enso	Stora Enso
Apr-99	International Paper & Union Camp	International Paper
Oct-99	Weyerhaeuser & MacMillan Bloedel	Weyerhaeuser
Feb-00	Abitibi Consolidated & Donohue	Abitibi Consolidated
Feb-00	UPM-Kymmene & Champion International	Champion International (uncompleted)
Feb-00	Stora Enso & Consolidated Papers	Stora Enso
Feb-00	Smurfit-Stone & St Laurent Paperboard	Smurfit-Stone
Mar-00	Nippon Paper & Daishowa Paper	Nippon Paper
Apr-00	Norske Skog & Fletcher Challenge Paper	Norske Skog
May-00	International Paper & Champion International	International Paper
Jun-00	Metsa-Serla & Modo Paper	Metsa-Serla
Jul-00	Georgia Pacific & Fort James	Georgia Pacific
Nov-00	Weyerhaeuser & Willamette	Announced (hostile)

A few large forest product companies now dominate the pulp and paper industry, as shown in Figure 2.7:

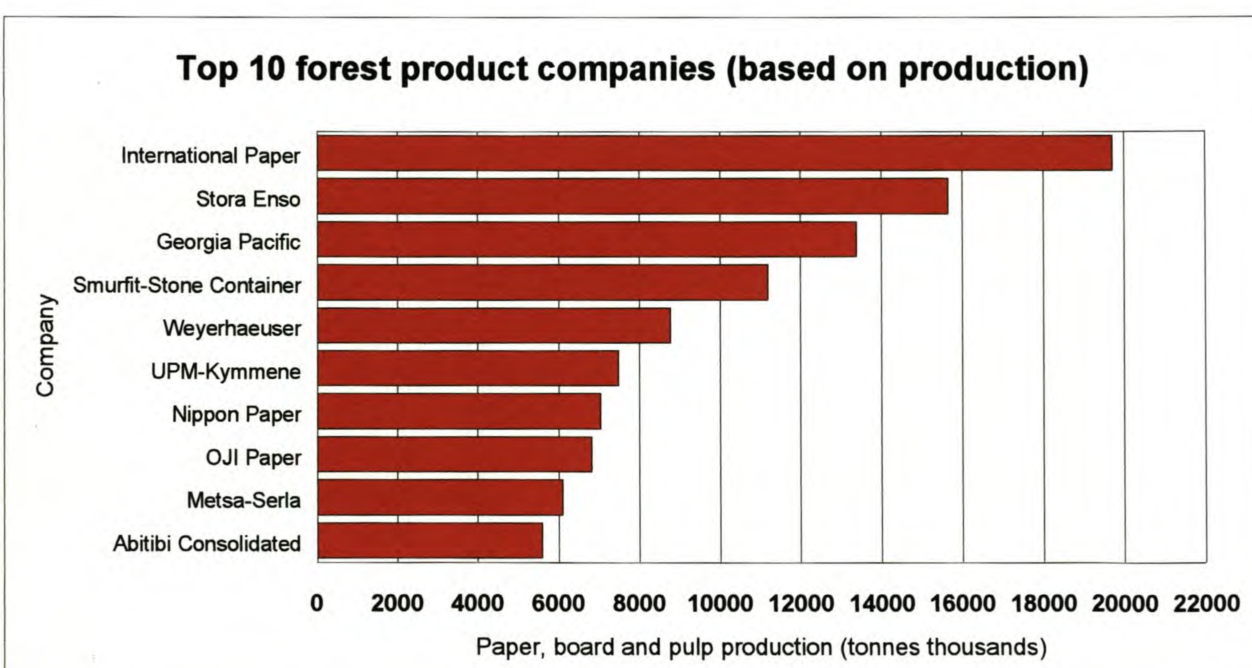


Figure 2.7: Paper, board and pulp production of the 10 largest forest product companies (Morkel, 2001)

2.2.4 Forest certification

Certification of forest products continues to be a high-profile and often controversial subject in the forest sector. In addition, tentative efforts are being made to extend certification to non-wood forest products, which would raise new issues.

Accurate statistics on the area of forests and volume of wood certified are difficult to obtain, and the figures are often difficult to interpret. The Forest Stewardship Council (FSC) reports that about 10.3 million hectares have been certified by FSC accredited certifiers. It is significant that 90 % of this area is in temperate developed countries, largely in Europe and North America. Sweden and Poland alone account for 58 % of the total. Thus, only a minor part is in tropical countries, where the problem of deforestation is greatest. The volume of wood involved and the volumes entering or about to enter the market are unknown, but are still insignificant in global and regional terms. The area of forests certified is not a sound indicator of the volume of wood entering the market, since parts of the certified areas may not be at harvestable age, may not contain commercial species or, in extreme cases, may not even have trees on them.

Certification efforts are being made at all levels. International efforts include those of FSC and the International Standards Organisation (ISO); regional initiatives include those of the African Timber Organisation (ATO) and the EU's Eco-Management and Auditing Scheme (EMAS) and Eco-Labelling Scheme; and countries with national programmes include Brazil, Canada, Finland, Ghana, Indonesia, USA and Sweden. In the last two years there have been many new initiatives, and a number of additional forests have been certified or are in the process of being certified. Among importing countries, interest continues to be greatest in Europe, especially Germany, the Netherlands and the United Kingdom. The exporting countries showing the most interest in certification are those whose main export markets are European countries and to a lesser extent the United States; hence the considerable effort Canada, Finland, Indonesia, Malaysia and Sweden have put into developing national certification systems (FAO, 1999).

Certification systems are based on evaluating the standard of forest management being practiced. The two main approaches, whose relative merits are a subject of considerable disagreement, are those of FSC and ISO. FSC favours a performance-based approach, i.e. stipulating that a specified standard of forest management, covering all aspects - including social aspects – must be achieved. ISO's approach is based on an environmental management system, i.e. stipulating that specific environmental management systems and commitment to specified actions and procedures, based on continuous improvement, must be in place. The FSC approach also considers chain-of-custody monitoring as an essential part of the process, while other certification approaches currently do not. Many consider chain-of-custody too difficult and expensive to put into practice.

Countries use one of these approaches, or a modified version, as appropriate to their own circumstances. While many consider the two approaches incompatible, there appears to be growing recognition that they may in fact be mutually supportive, and that a degree of mutual recognition could eventually be achieved. It is also recognised that without this mutual recognition, progress will be fragmented and difficult (FAO, 1999). Even within an individual country, different approaches are being followed by different groups. Sweden, for example, recently announced that agreement had been reached between the large forestry companies and FSC on a certification system based on FSC's principles. However, small forest owners in Sweden have rejected this system and have decided to follow their own approach.

For many countries an important aspect of certification is its relevance to and impact on its small forest owners. This is an important issue in countries where a high proportion of the forest land is owned by a large number of owners, many of whom have very small areas of forest — often less than 10 ha. Similarly, in France, some 4 million private owners own almost 10 million hectares of forests — an average holding of 2.8 ha per owner. Even in the United States, where large private companies own substantial forest areas, some 60 % of the commercial certification is based on the proportion of certified fibre in the final product. This would allow certification of products without requiring that 100 % of the fibre used comes from certified sources.

The following are some of the most significant developments that have occurred in the past two years.

- In Canada, the Canadian Standards Association (CSA) has developed an ISO-based certification system. The system allows individual companies to be certified by a third party assessor using standards developed by CSA.
- In a related move, an ISO Forestry Working Group has prepared a technical report to assist forestry organisations in implementing the 130-14001 Environmental Management System Standard. The report provides information on forest principles, criteria and indicators of SFM that have been developed by various other groups.
- The Netherlands and Germany have been working on the development of methods of validating the certificates provided by suppliers (both domestic and foreign) to their markets and of linking these certificates to final products in their markets. The Keurhout Foundation in the Netherlands has developed a system that will assess suppliers' certificates and monitor the chain-of-custody (i.e. track the raw material through to the final product form) to the end user. A "hallmark stamp" (i.e. a so called "eco-label") is available for final products.
- The American Forest and Paper Association (AF&PA) has spearheaded a Sustainable Forestry Initiative (SFI) by which its member companies commit themselves to practice sustainable forestry management. This commitment is a compulsory requirement of membership in AF&PA. It is not a certification process, but the principles and guidelines applied by companies may serve as a basis for future certification by an independent body.
- FSC has continued to expand its coverage, both in terms of area certified and country participation, and has developed an FSC label to be placed on certified final products. This label is available for use on supplies certified by FSC accredited certifiers (FAO,1999).

Despite these efforts, there are still unresolved or unanswered questions surrounding certification and uncertainty as to how it may develop in the future. There is still little evidence of the market impacts of certification, positive or negative. The most obvious sign of growth in certification activities is the area of forests certified, but there are few signs of significant volumes of certified products entering the market. In part, this is because certified supplies remain limited, but it may also reflect a lack of buyer interest.

It remains unclear whether demand for certified wood products will increase and whether consumers will be prepared to pay a price premium for them. Even in the markets showing the greatest interest in certification, there is little sign of a substantial or increasing demand, or any price premium paid. A number of market studies have concluded that there is little evidence of a significant demand for certified products.

Another unanswered question is whether certification will in fact significantly contribute to improved forest management where deforestation is greatest in the developing countries. Certification was originally promoted by environmental groups as a market-based lever to improve forest management and to reduce deforestation, particularly in tropical rainforests. At present, those certifying or trading in certified products seem to be using it more as a marketing tool either to generate an increasing market share or to ensure continued or improved access to markets. Some forest owners, however, see certification as benefiting their forest management practices in addition to providing certain market benefits.

Despite these uncertainties, interest in certification continues to grow. It seems clear that at least in the short- to medium-term, the area of forests being certified will continue to expand as major producing countries such as Canada, Finland, Indonesia, the USA and Malaysia finalise the systems they are developing. It is still difficult, however, to predict where certification will finally arrive and what type of system, or combination of systems, will be favoured. The results will depend heavily on which markets institute it, the degree of support given by consumers, legislators and traders in these markets and the extent to which mutual recognition of different practices is achieved. Certification may well expand and have a significant impact in some markets, but equally, it could remain limited to a few markets and a few specific end uses (e.g. high-value furniture). It is also possible that in the long-term it could fail to have any significant impact. The deciding factor will be consumer reaction to the products, which is far from clear at this stage (FAO, 1999).

2.3 Developments in South Africa

2.3.1 Early developments

Harvesting in South Africa, prior to the turn of the last century, was strictly limited to extracting hardwood timber from the country's indigenous forests. The advent of the industrial age soon showed that the local timber resources were inadequate to meet the growing need for timber products and the establishment of exotic timber plantations became necessary. The limited usefulness of indigenous timbers for general purposes, coupled with an increasing demand for the protection of the country's natural resources, caused logging operations in the forests to come to a virtual standstill. At the same time the afforestation of suitable areas with exotic plantations created the need for a specialised approach to harvesting in order to extract the timber from the new plantations. The conventional European and American harvesting methods had only a limited application and had to be partly adapted to suit local conditions, as the country is not well supplied with natural waterways for timber transport or a ground cover of firm snow during the winter months to aid transportation or extraction operations by sled (Zaremba,1976).

2.3.1.1 Historical review of pine operations

Prior to the introduction of some mechanisation in harvesting, the timber harvested was generally of small size and the areas yielding mature timber comparatively small. Trees were generally felled by men using axes and cross-cut or bow saws, depending on the size of the trees. In order to move timber from stump to the roadside, men carried the smaller logs while teams of oxen or mules were usually used to slip the larger ones. Yokes, simple harnesses and pulling chains were commonly used on the animals for log slipping.

For debarking, axes, draw-knives or vineyard spades were commonly used. Roads were, as a rule, constructed by manual labour. Warkotsch (1986) described the evolution of harvesting systems, as depicted in Figure 2.8.

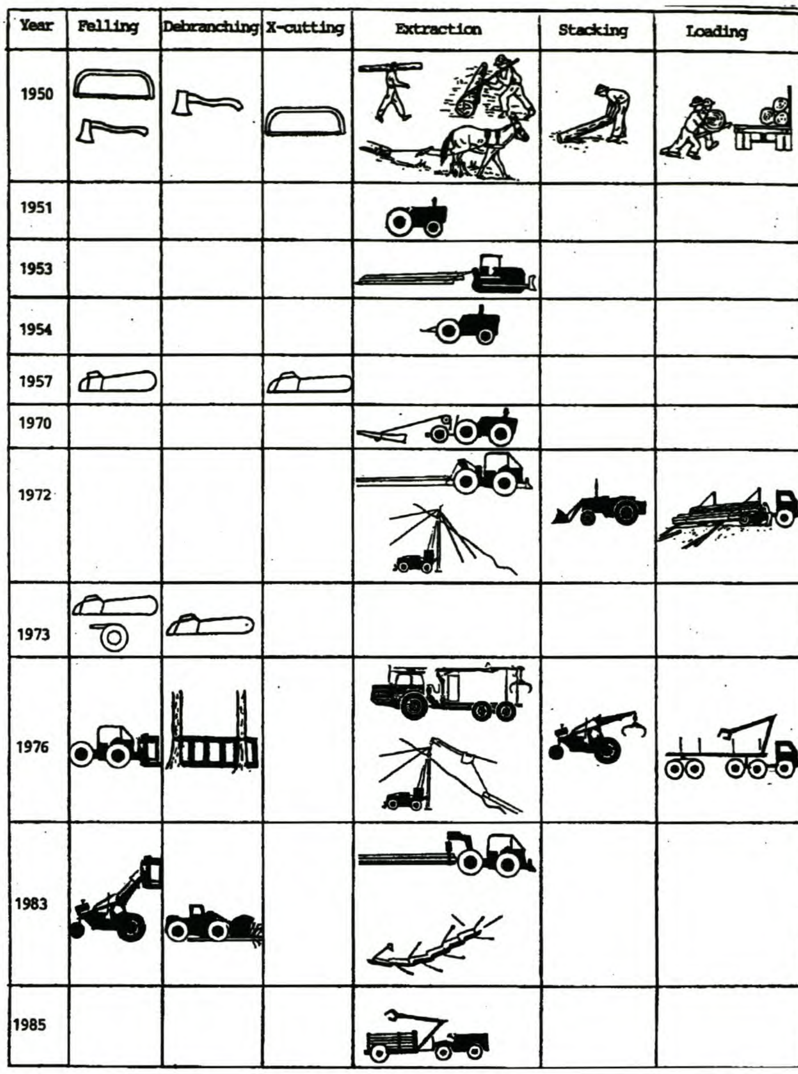


Figure 2.8: *Evolution of harvesting methods in South African pine plantations (Warkotsch, 1986)*

The following factors brought about the introduction of and increased use of mechanisation in logging in the 1960's and 1970's:

- the increased size of timber being harvested;
- the larger areas of mature yield to be extracted;
- acceleration of all logging operations. Fires in particular necessitated the fast extraction of burnt timber;
- mechanical equipment was less dependent on terrain and surface conditions; and
- mechanical equipment was less dependent on weather conditions (Zaremba,1976).

Warkotsch (1986) confirms the influence of timber size on mechanisation and states that this was a major contributory factor towards the mechanisation of harvesting operations. Agricultural tractors (first introduced in 1951), later equipped with lifting bars, were employed on easier terrain for slipping large logs. In steep terrain crawler tractors (first introduced in 1953) came into operation. Mules were mainly used for slipping logs of smaller diameters from thinnings and mining timber plantations.

The increased productivity achieved by the slipping units created pressure on the felling teams. Consequently, the chainsaw was introduced for felling and crosscutting in 1957. In the 1970's, mechanical and manual logging methods were employed side by side, depending on local conditions. Felling and log preparation were only partially mechanised, chainsaws being used in conjunction with handsaws. Timber extraction from stump to roadside was also partly mechanised, crawler tractors being used in conjunction with mules and oxen. High-lead units and cableways were used primarily for difficult, steep and inaccessible terrain, irrespective of the log sizes harvested. Tractors were generally employed on easier terrain for slipping large logs. Mules and oxen were mainly used for slipping logs of smaller diameter from thinning operations, dependent on the terrain, but teams of animals were sometimes used for extracting large logs on downgrades in small, isolated plantations (Warkotsch, 1986).

As is the case today, labour was fairly abundant in South Africa in the past, which restricted the move to mechanisation for economic and social reasons. A perception at the time of high labour costs and the scarcity of labour in the Western Cape did, however, tend to stimulate mechanisation in this region. The adaptability of labourers to new techniques was slow, but not necessarily a retarding factor in the use of mechanised operations (Zaremba,1976).

Table 2.2 shows the timber yield of each region of the Department of Forestry in 1961, as well as the tools used for log preparation and extraction, after Zaremba (1976).

Table 2.2: Timber yield and logging equipment distribution, as in 1961 (Zaremba, 1976)

Region	Planted area	Volume			Log slipping			Power saws	Cranes		High lead	
		Thinning	Clearfelling	Total	Oxen	Mules	Tractors		Self propelled	On trucks	On trucks	On tractors
	Ha	m³	m³	m³								
N.Tvl F.D. S.A.B.T.	13 678 4 160	52 723 7 782	75 439 1 330	128 162 9 112	131	61	11	14	1	1	1	
E.Tvl F.D.	59 038	127 972	113 200	241 172	271	194	28	24	5	1	-	1
S.Tvl F.D. S.A.B.T.	27 439 1 367	68 404 1 132	87 764 4 245	156 168 5 377	102	27	7	14	2			
W.Cape F.D.	18 393	30 609	34 025	64 634	3	113	5	13			1	1
S.Cape F.D.	47 430	101 031	144 981	246 012	6	262	25	15	1		2	2
E.Cape F.D. S.A.B.T.	15 435 8 242	17 829 -	28 753 -	46 582 -	60	67	6	6				
Transkei F.D. S.A.B.T.	154 22 035	- 45 195	- 4 047	- 49 242	 94	 26		 3				
Natal F.D. S.A.B.T.	13 383 12 089	15 565 8 490	97 635 1 415	113 200 9 905	24 82	86 4	10	13	2			
Zululand F.D. S.A.B.T.	30 351 6 733	30 833 -	44 544 -	75 377 -	227	9				1		
Saasveld	1 342	-	-	-								
TOTAL	281 269	507 565	637 378	1 144 943	1 000	849	92	102	11	3	4	4

F.D. = Forest Department

S.A.B.T. = South African Bantu Trust

(Zaremba, 1976).

Logs were primarily transported by seven – 10 ton trucks to the sawmills. Loading was partially mechanised, but in the majority of small, isolated plantations logs were loaded manually.

The initial mechanisation of logging operations did in many ways affect the forestry industry and working conditions for the people involved, e.g.:

Machines reduced the backbreaking strain of men working in harvesting operation in the following ways:

- the work was carried out quicker;
- labour was reduced considerably;
- machines demanded more skilled operators;
- maintenance of the machines required specially trained staff and the establishment of workshops.

This required a higher degree of skill and efficiency from the operators employed than before (Zaremba, 1976). The chainsaw operators were trained, in a countrywide campaign to apply the Nordfor method, in 1973 and only three years later the first feller buncher was imported. This resulted in a new bottleneck with the stacking of logs at the forest road and at the landing with tree-length skidding. Agricultural tractors replaced manual stacking but did not really overcome the problem. The answer was the three-wheeled, hydrostatic Bell loader - a machine originally designed for sugar cane loading. While some companies decided to apply tree-length skidding, others decided to invest in forwarders. The subsequent deterioration of the exchange rate, lack of local expertise and back-up services resulted, however, in a phasing out of imported forwarders. When the plantations that had been established in mountainous areas became mature, high lead and skyline operations were implemented to extract timber from these areas.

The mechanisation of debranching always received special attention. Gate debranching was tested in 1976, followed by the development of a locally designed chain flail. Debarking is normally done at depots or at the mill yards. Mainly rotor as well as drum debarkers were used depending on the assortment and scale of operation (Warkotsch, 1986).

2.3.1.2 Historical review of eucalypt operations

Traditionally, the harvesting of eucalypt plantations was conducted by the use of labour intensive methods for felling, debarking, crosscutting and vehicle loading. Figure 2.9 gives an overview of these developments between 1950 and 1985, after Warkotsch, (1986). The bow saw and the hatchet were commonly used. The extraction and transport consisted of driving a rigid truck down a row infield, using a loading crew to hand load the timber consisting of 2,4m lengths. At the mill or the depot the same loading crew off-loaded the timber.

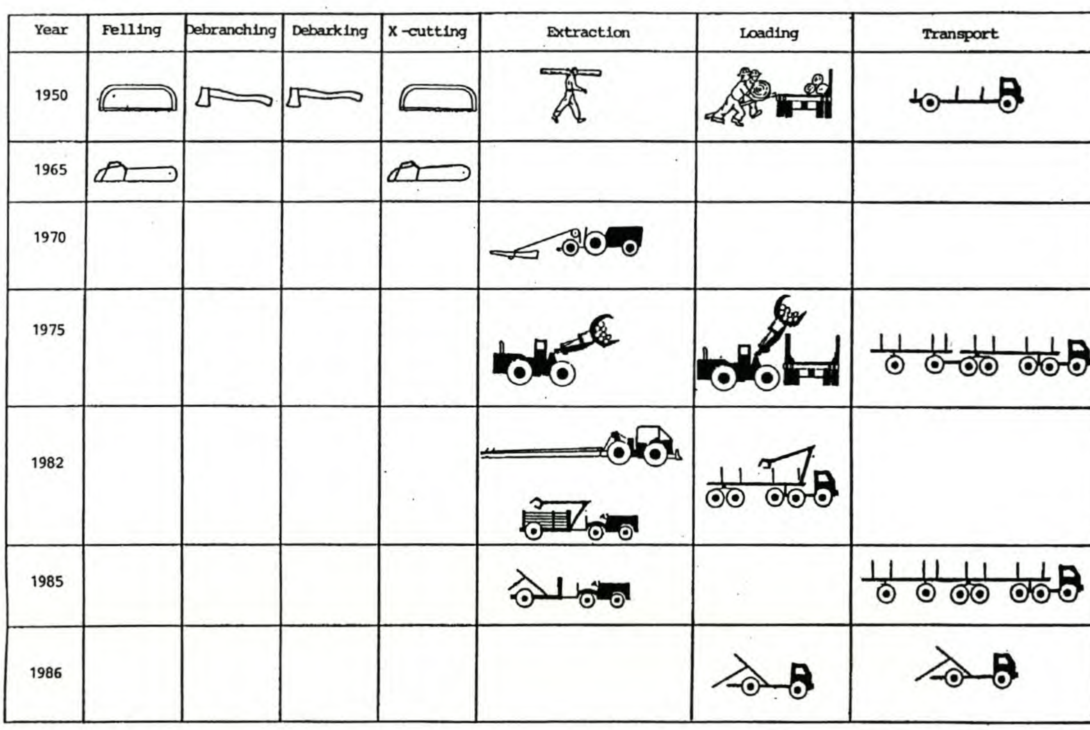


Figure 2.9: Evolution of harvesting methods in South African eucalypt plantations (Warkotsch, 1986)

Problems with the recruitment of labour resulted in the introduction of chainsaws (in 1965) for felling and crosscutting. For extraction, agricultural tractors (1965), front-end loaders (1975), tractor-trailer configurations (1980) and self-loading bundle tractors (1985) were introduced. Testing of tree-length extraction was tried in the 1980's. The piece-volume principle caused problems for cable skidders as well as grapple skidders and the extraction of tree-lengths with a front-end loader never became a success due to high downtime and high maintenance costs (Warkotsch, 1986).

2.3.1.3 The development of forest roads

Several attempts have already been made in the 1960's and 1970's to mechanise logging as a means to reduce the length of roads to be constructed for timber transportation, but it was found that a well-planned system of roads provided the best access to the planted area, besides serving the needs for fire protection purposes.

Zaremba (1976) established the following general guide for road densities, to serve as a rough basis for road planning where one-way skidding was used on slopes:

- First quality sites: 10 – 11 ha/km
- Second quality sites: 12,5 – 15 ha/km
- Third and poorer quality sites: 17,5 – 20 ha/km

For flat, mild or easily accessible terrain the above figures may have been as much as doubled, with a maximum of twice the given area served per kilometre of road.

Table 2.3 shows the approximate planted area of each region of the Department of Forestry, the approximate length of existing roads in 1961, and the density thereof (Zaremba, 1976).

Table 2.3: Road length and road density in South African forestry in 1961 (Zaremba, 1976)

Region	Planted area	Existing roads	Road density
	Ha	Km	Ha/km
Northern Province	18 000	1 160	15
Mpumalanga North	59 000	2 760	21
Mpumalanga South	29 000	1 155	25
Western Cape	18 000	740	24
Cape Midlands	47 000	2 500	19
Southern Cape	1 400	48	29
Natal	26 000	777	34
Eastern Cape	16 000	880	18
Zululand	37 000	820	45

2.3.2 The Forest Technical Survey

As part of this study, a survey was undertaken to establish the current situation in SA regarding the activities in the Forest Engineering value chain. A similar survey was conducted for the first time in South Africa in 1987 (Warkotsch & Brink 1989) and was modelled on the Austrian Forest Technical survey, which has been conducted in that country at 5-year intervals since 1975. The survey reported on here was a repetition of the 1987 survey but, in addition, included suggestions for improvements made by Brink (1989). DWAF undertakes an annual census of forestry statistics (DWAF, 1998), but unlike their census, which is essentially macro in its approach, the Forest Technical Survey (FTS) approach is micro, providing detailed information on activities in the harvesting field, covering aspects such as labour, systems and machinery. The aspects covered in this survey are analysed by timber species, by plantation size, by geographic region and by type of labour used (e.g. own *vs.* contractors).

The information contained in the survey provides a useful planning tool for forest managers, contractors and manufacturers and distributors of equipment. Some of the more important benefits to be gained are listed hereunder:

- The forest manager will be given greater insight into problem areas of harvesting and transport, will become more aware of the different systems and equipment available, and will generally be able to improve competency in compartment planning and the opening up of forest roads.
- Harvesting and transport contractors will be able to assess their present situation better and to estimate possibilities for expansion more easily, through being able to make more reliable estimates of the size of the potential market and what the present market consists of.
- Manufacturers and distributors of equipment will be in a better position to determine their target market, the size thereof and strategies to penetrate such market segments.

  (Brink,1989).

The survey serves as a point of departure for the forecasting methodologies applied in Chapter 5. Without a sound foundation of the current position in South Africa, it will be difficult to establish future trends.

2.3.2.1 The survey description

The survey was conducted by means of a questionnaire. This method was considered to be the most practical in view of the large number of participants and their wide geographic distribution.

To ensure that a high response rate was achieved, the questionnaire was made as concise, simple and understandable as possible. Annexure 1 contains an example of the questionnaire.

The questionnaires, with pre-addressed reply envelopes were mailed to participants in April 1997. At the beginning of June 1997, a second questionnaire was mailed to non-respondents, and during August and September 1997 all those who had still not responded were contacted by telephone. The cut-off point for responses was 30 November 1997.

The original intention was to reach all registered tree growers in South Africa, and to this end DWAF's mailing list used for their annual forestry census was obtained. This list contained the names and addresses of some 2 000 tree growers.

Returned questionnaires, representing plantation areas of less than 200 ha ,were ignored. This was done to avoid skewing of the data, as many of these areas are combined with agriculture. Collectively, these small units represent 7% of the total afforested area in South Africa (i.e. 78 104 ha of a total of 1 159 780 ha).

The sample size in terms of the questionnaires distributed is given in Table 2.4:

Table 2.4: Questionnaires evaluated in terms of plantation units and afforested area

Description	Survey	Industry	Survey as % of industry
By plantation units	648	1490	43%
By afforested area (ha)	1 457 627	1 518 138	96%

A very high response rate was achieved, as illustrated in Table 2.5. The response rate is specifically compared with the DWAF (1998) statistics, as these correspond with the year in which the FTS questionnaire was sent out to the industry.

Table 2.5: Questionnaire response rate

Description	Response rate	Industry	Response as % of Industry
By afforested area (ha)	1 038 322	1 518 138	68%
By plantation production (m^3)	12 892 588	18 078 224*	81%

**Period April 1996 to March 1997 (DWAF, 1998)*

In view of the high response rate to the questionnaires distributed and the coverage thereof to the total industry situation, the analysis and results of the survey were regarded as representative and valid. All data have been extrapolated to reflect the total industry production, expressed in m^3. The structure of the FTS closely follows the format of the questionnaire in which four specific issues were covered, viz.:

- Forestry Industry statistics;
- labour situation in harvesting;
- harvesting systems, methods and machinery; and
- forest roads and transport statistics.

A report on the most important results of these four issues are graphically represented and discussed in the following paragraphs.

2.3.2.2 Forestry Industry statistics

The geographic breakdown of the afforested area and annual cut is summarised in Table 2.6:

Table 2.6: Plantation area and roundwood production (DWAF, 1998)

Forestry region	Afforestation		Roundwood production	
	Area (ha)	% of total	Volume (m³)	% of total
Mpumalanga and Northern Province	686 612	45%	9 400 676	52%
KwaZulu-Natal	577 896	38%	7 592 854	42%
Eastern & Western Cape	253 630	17%	1 084 694	6%
Total RSA	1 518 138	100%	18 078 224	100%

Figure 2.10 describes the annual cut from the surveyed plantation area by geographic region and species for the year ended March 1997.

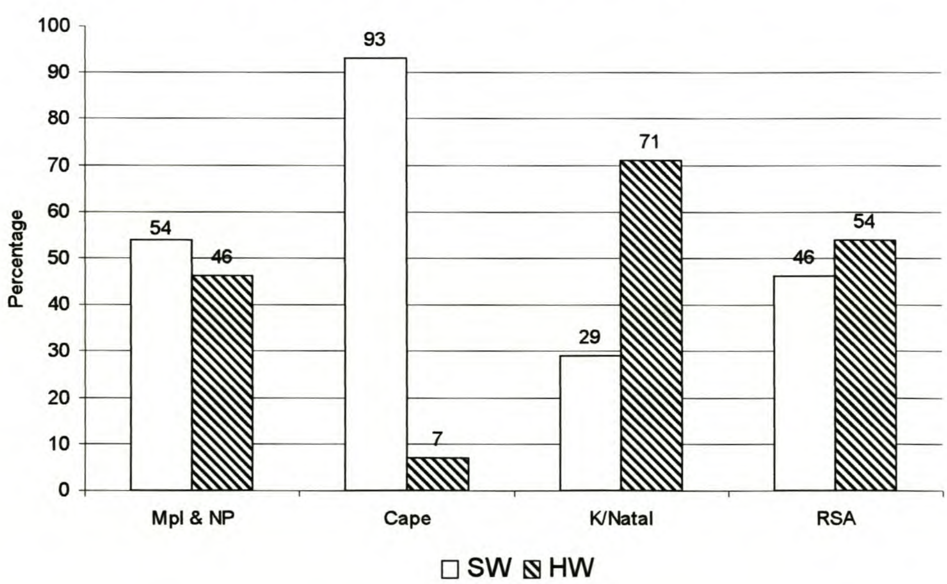


Figure 2.10: Annual cut by species and region

The softwood (SW)/hardwood (HW) ratio (Figure 2.10) of the total annual cut in terms of the FTS is approximately 1:1. While the situation in Mpumalanga and the Northern Province is similar to that of the total RSA (1:1), KwaZulu-Natal cuts more hardwoods and the Cape Province significantly more softwoods.

As shown in Figure 2.11, softwood and hardwood production is approximately evenly balanced, except for plantations in the 2 000 – 4 999 ha, 5 000 – 9 999 ha and > 10 000 ha categories. The plantations > 10 000 ha in size are mostly owned by corporates and more hardwood orientated.

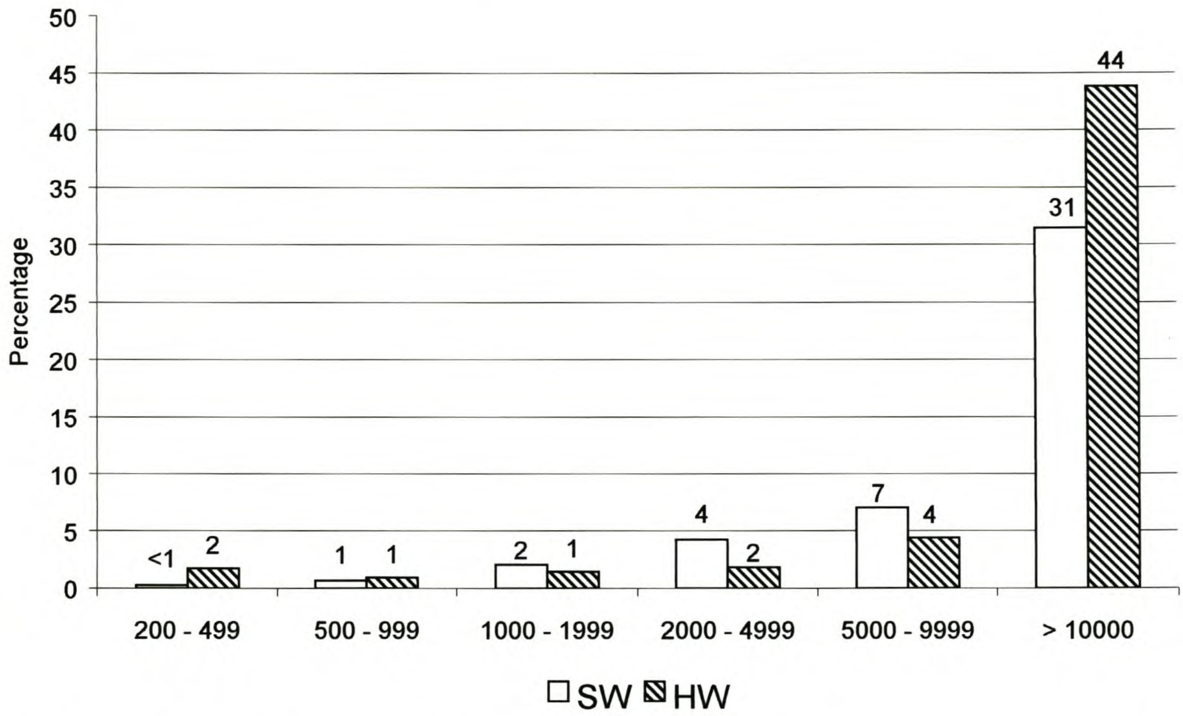


Figure 2.11: Annual cut by species and plantation size ratios

Figure 2.12 shows the ratio of clearfellings to thinnings to be 6:1 in softwood. Softwood thinnings contribute substantially more than hardwood thinnings (14% vs. 1%) due to the different silvicultural regimes employed. The reason for this is that hardwoods are primarily grown for the pulp market, while a substantial portion of softwoods require thinnings because of a sawtimber regime.

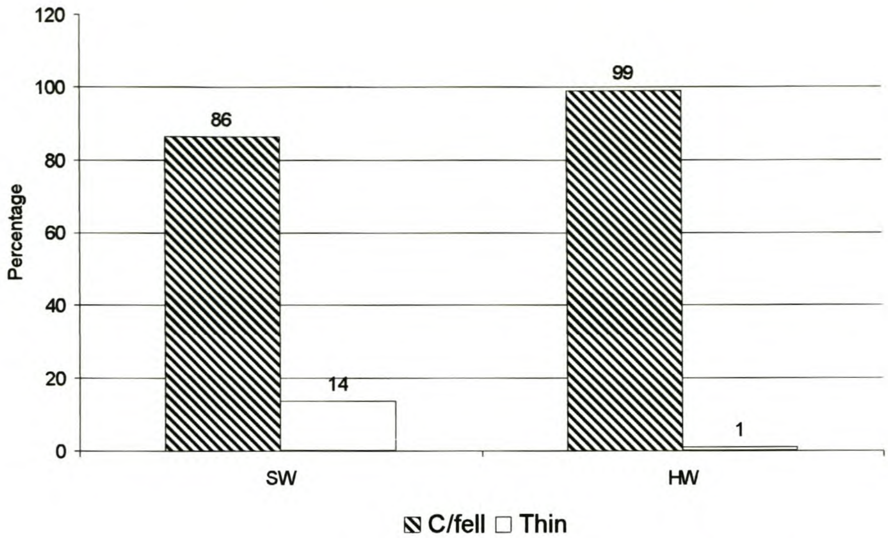


Figure 2.12: Thinning vs. clearfelling ratios (percentage of volume harvested)

2.3.2.3 Labour statistics

The breakdown of the labour options employed in harvesting operations in the various Provinces is shown in Figure 2.13.

Figure 2.13 shows that the current trend in harvesting throughout all the forestry regions is that 62% of harvesting is done by contractors. Own labour harvesting is the most popular alternative to the use of contractor labour, and, on average, 35% of all harvesting operations are done in-house. The category "other" relates to timber sold standing. The Cape varies significantly from the rest of the country, however, with 60% of all harvesting operations conducted in-house.

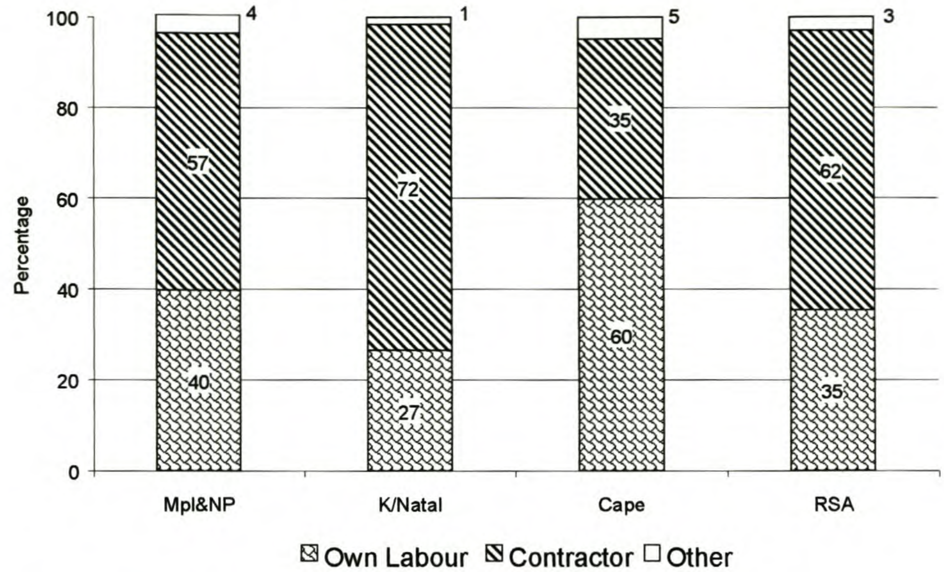


Figure 2.13: Harvesting operations: Own labour vs. contractor

The length of time that labour has been employed plays an important role in the level of skills obtained on the job. It is therefore important for management to keep labour turnover as low as possible. Turnover is determined *inter alia* by:

- average length of service;
- average age of the workforce; and
- the employment level of the individual.

It is also important for labourers to be motivated in their task and to make the job as enriching as possible. Major factors of importance for job satisfaction are:

- seeing to his/her social needs;
- wage levels that are competitive and in line with industry standards;
- allowing more freedom and greater participation in the decision-making process; and
- ensuring a free flow of communication between management and labour. (Brink, 1989).

The employment periods of labour in harvesting and silviculture operations are compared in Figure 2.14. These two disciplines follow very much the same employment period pattern.

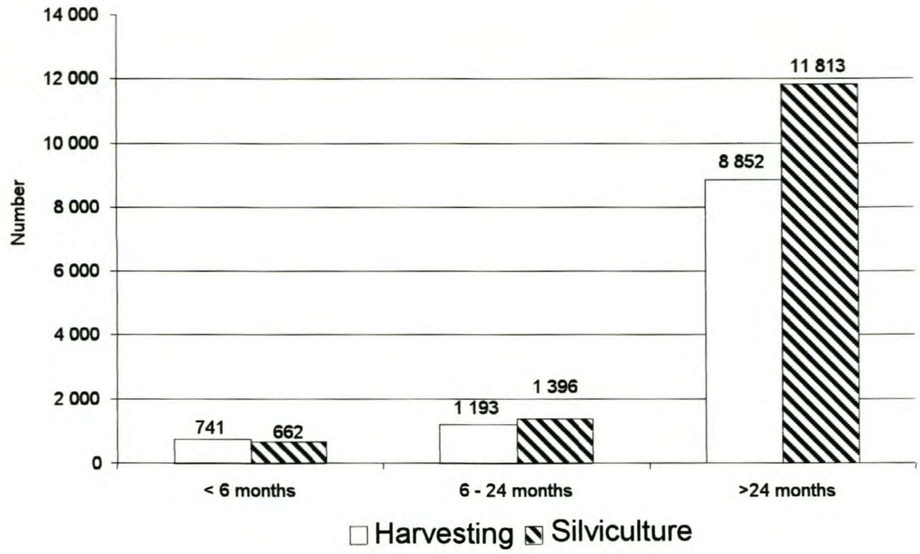


Figure 2.14: Labour employment period: Harvesting vs. silviculture

As at the end of 1997, some 10 786 labourers were employed in harvesting operations throughout the country (Figure 2.15), with 5 754 (53%) being male and 5 032 (47%) female. The labour force in silvicultural operations was 13 871. An interesting fact that emerged from the FTS is that in harvesting, for labour employed for 6 months or less, female labour exceeded male labour. This indicates a higher labour turnover rate in the case of females, with 20% being employed for less than 2 years. By comparison, 16% of males had been employed for less than two years.

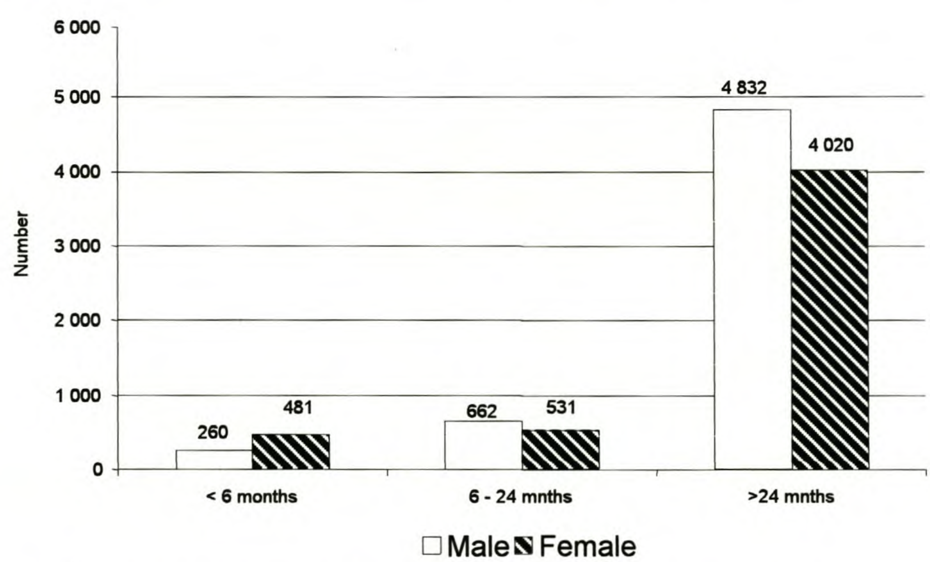


Figure 2.15: Labour employment period in harvesting: Male vs. female

Figure 2.16 reflects the remuneration methods used. Note that internal company systems dominate, as most companies have in-house work study norms, which are used to base daily output targets on. However, the data does exclude the payment methods used by contractors.

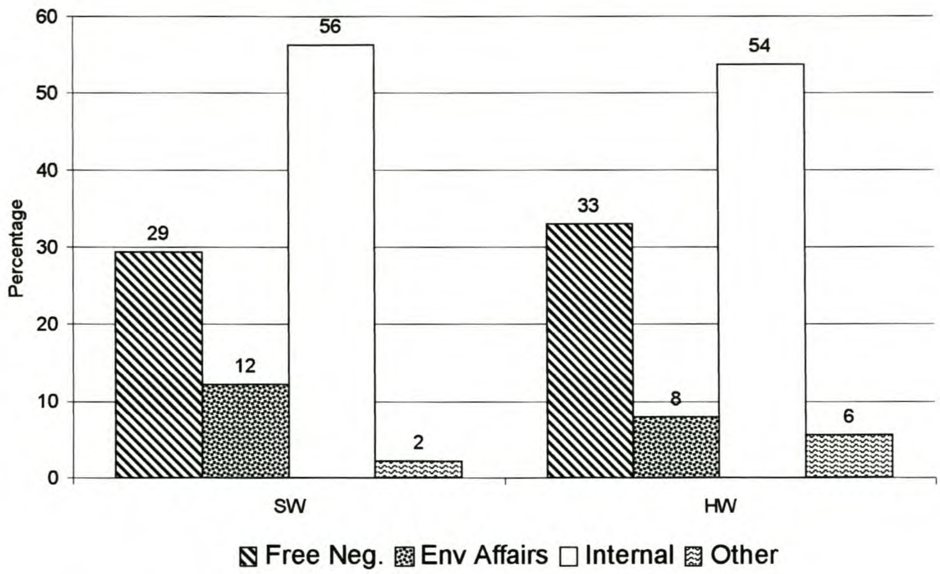


Figure 2.16: Remuneration methods

2.3.2.4 Harvesting statistics

Felling by chainsaw is the most commonly used method in South Africa. According to the survey data received, and based on the assumption that each chainsaw operator uses two chainsaws, the estimated chainsaw population in South Africa is 4 000.

Figure 2.17 shows that there are some 2 000 chainsaw operators in South Africa, equivalent to 26% of the male labour force employed in harvesting operations. Of these, 333 operators use felling aids and 670 have assistants using push rods during felling. In terms of production based on the annual cut of 18 078 224 m^3, the overall average output is 8 985 m^3/operator/annum.

Three harvesting methods have been analysed, viz. cut-to-length, tree-length and full tree harvesting, details of which are shown in Figures 2.18, 2.19, 2.20 and 2.21.

The definitions for the three harvesting methods analysed are as follows:

- Cut-to-length: clearly debranched shaft (with or without bark), which can be either in short-or long lengths (>6 m).
- Tree-length: clearly debranched shaft from the butt to the top (the top of the tree can be cut off).
- Full tree: includes branches (but excludes roots).

These definitions refer to the form of the timber when it arrives at the landing or depot. Merchandising at the landing and the type of transport configurations used are therefore excluded. Each of the three harvesting methods can vary from very labour-intensive to totally mechanised, for example CTL pulpwood can be felled, debranched and crosscut by chainsaw and hand-loaded onto tractor/trailer units. Conversely, a harvester and forwarder can be used to prepare CTL pulpwood logs at roadside. Where applicable, labour intensive CTL systems is referred to as CTLL and mechanised CTL systems are referred to as CTLM.

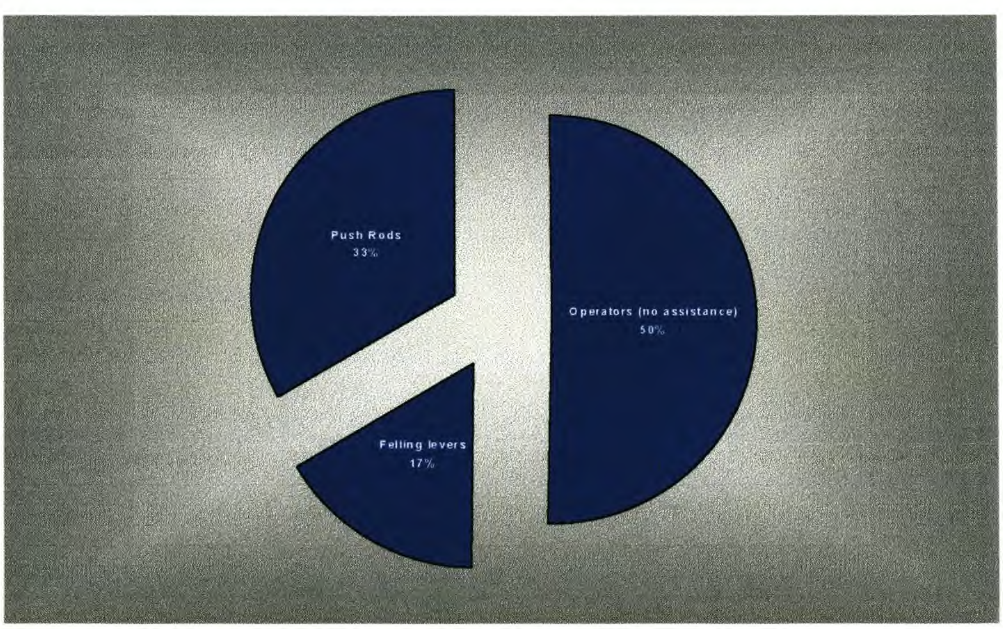


Figure 2.17: Chainsaw operators employed

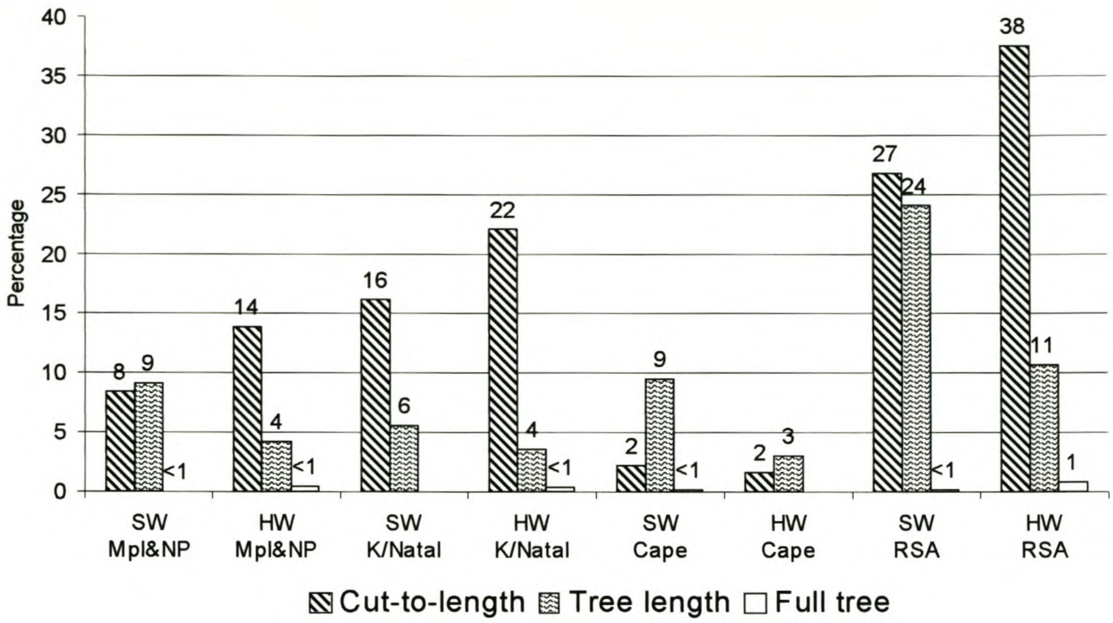
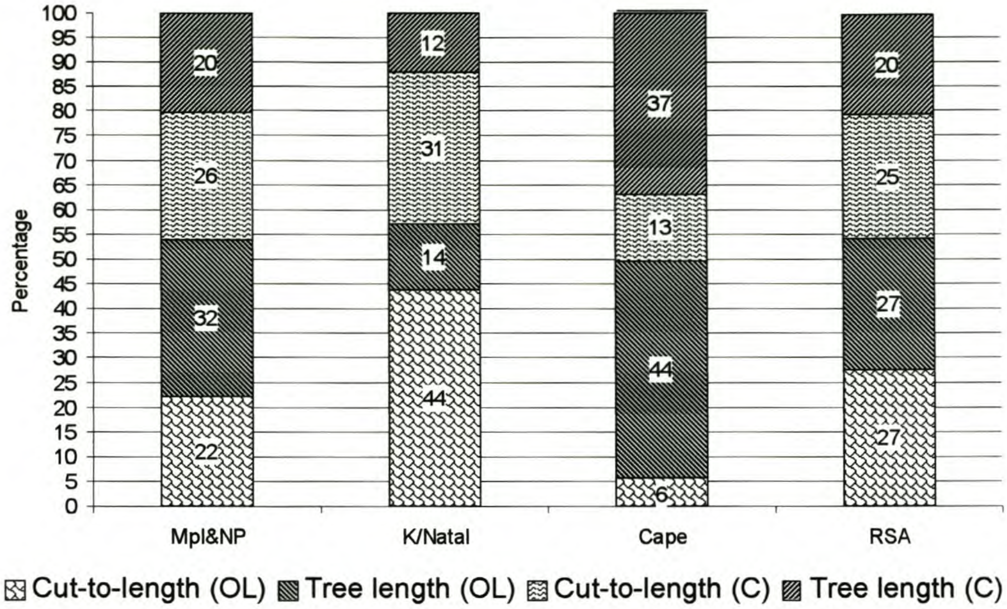


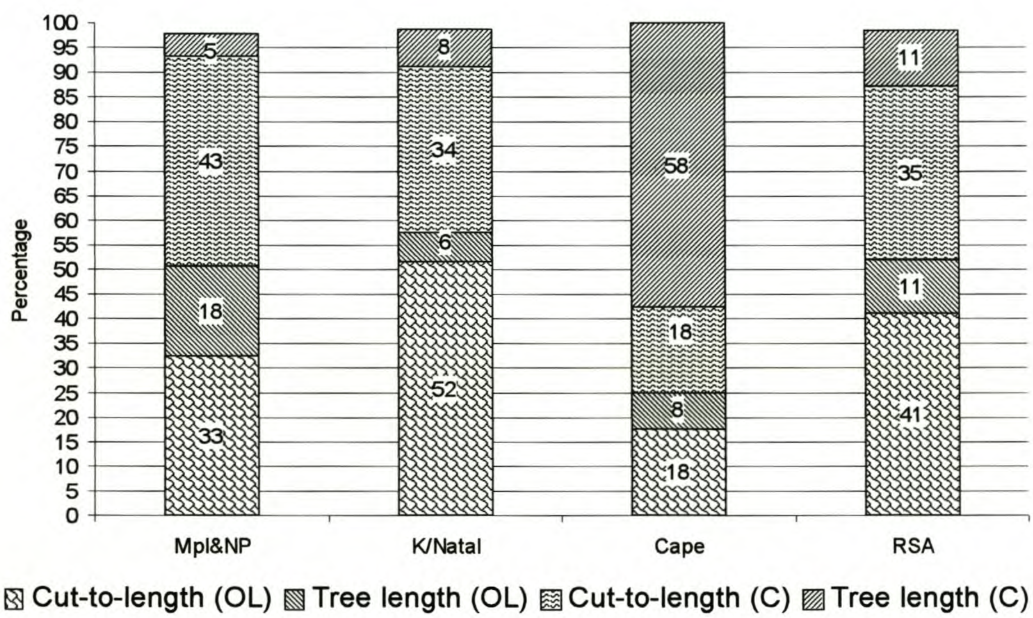
Figure 2.18: Harvesting methods used, by province and species

Figure 2.19: Harvesting methods used: Own labour vs. contractor



Note: *1% full tree harvesting is omitted from graph due to insignificance.*

Figure 2.20: *Softwood harvesting methods: Own labour (OL) vs. contractor (C)*



Note: *1% full tree harvesting is omitted from graph due to insignificance.*

Figure 2.21: *Hardwood harvesting methods: Own labour vs. contractor*

Figure 2.18 clearly indicates that most timber is harvested by the cut-to-length method. Hardwoods are dominated by cut-to-length (38% of the total annual cut), while softwoods are more evenly balanced between cut-to-length and tree-length. Of interest is the fact that full tree harvesting is virtually absent in South Africa (less than 1%). From Figure 2.19 it is shown that 53% of cut-to-length harvesting is carried out by own labour as opposed to contractor harvesting (47%). The ratio is similar for tree-length. Figure 2.20 shows the dominance of cut-to-length in softwood in KwaZulu-Natal, using contractors, while the harvesting of tree-lengths with own labour predominates in the Cape. The same is true for hardwood harvesting in Mpumalanga, the Northern Province, and KwaZulu-Natal (Figure 2.21).

During the last few years there has been a great deal of interest in mechanised debranching world-wide, mainly to overcome the disadvantages of chainsaw debranching, which are:

- high cutting costs;
- labour intensity;
- high chainsaw accident rates; and
- negative ergonomical effects (Brink, 1989).

Machines designed for combined debranching, crosscutting and/or debarking of pre-felled trees are classified as processors. If the felling function is included with the former definition, the machine is classified as a harvester.

An analysis of the debranching methods used in South Africa is illustrated in Figure 2.22.

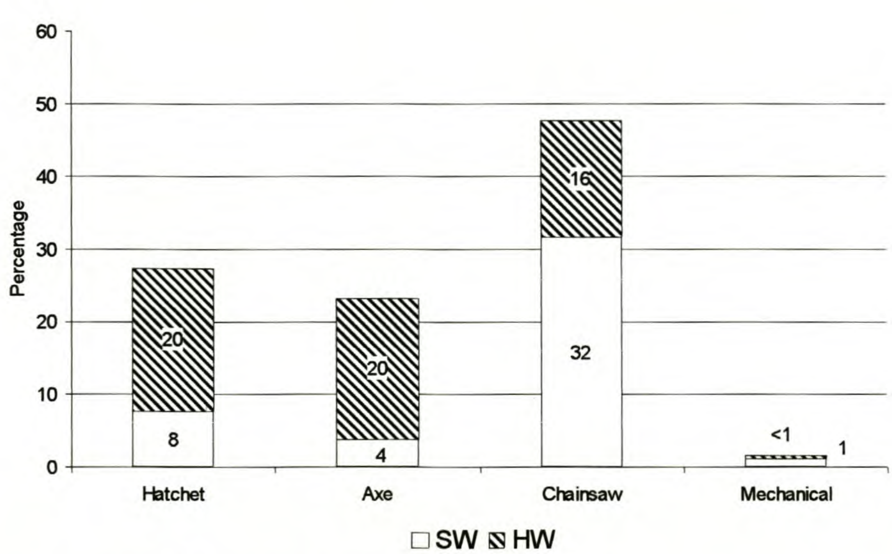


Figure 2.22: Debranching methods used in South Africa

Figure 2.22 shows chainsaw debranching to be the most frequently used method (48% of total). This is particularly so for the debranching of softwood (32%), whereas in the case of hardwoods the use of hatchets and axes dominates (20%). Mechanical debranching is still very low in South Africa, totalling 1%.

In South Africa, axes are mainly used for manual debarking. Mobile debarking machines can be divided into:

- portable machines, manually handled with its own engine;
- machines pulled, and driven by the power take-off of a tractor; or
- self-propelled vehicles.

Figure 2.23 shows that 38% of the annual cut is sold with bark (36% softwood and 2% hardwood), and that the major portion of hardwood is debarked manually (51%). Due to the problems faced with mechanised hardwood debarking, only 1% of the total volume harvested is debarked by infield machines.

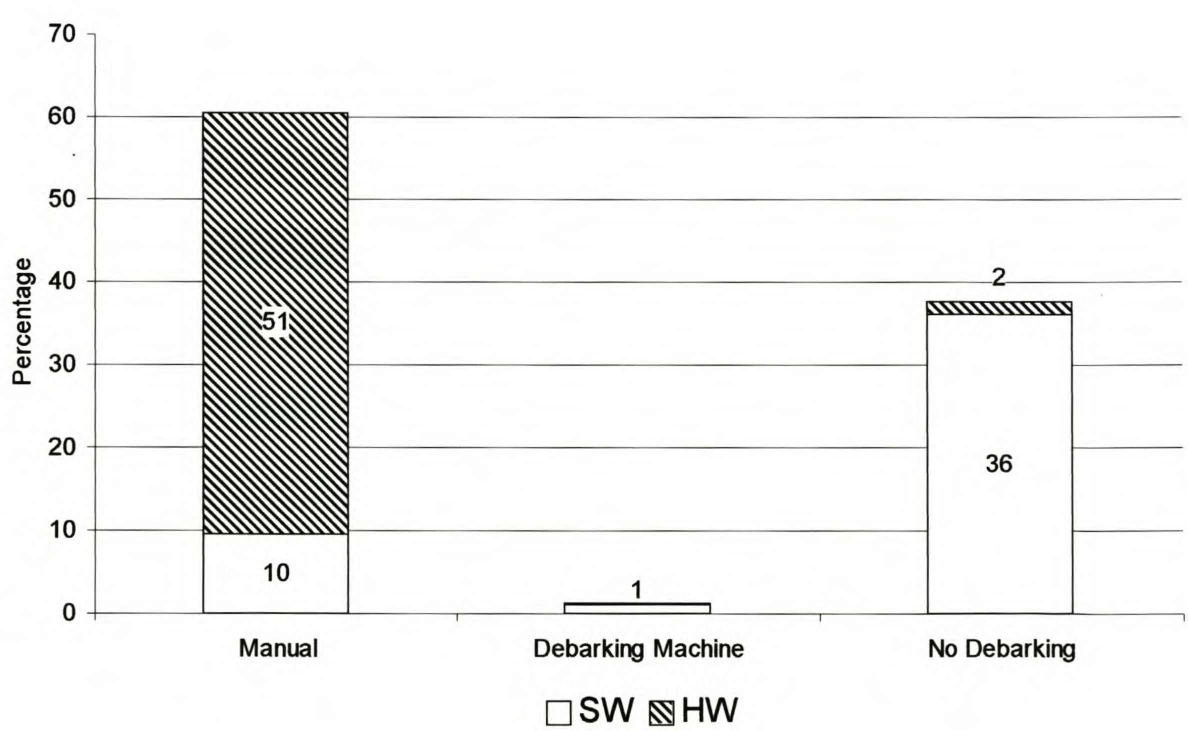


Figure 2.23: Debarking methods: Softwood vs. hardwood

Manual extraction is defined as a combination of the carrying and rolling of logs to roadside or to extraction routes. It must be noted that the DWAF plantations are included in the survey, which are more labour intensive. Manual extraction is the most popular extraction system for hardwoods (15%), followed by forwarder extraction and infield trucks (Figure 2.24). Cable skidders, at 11%, are the most popular extraction method for softwoods.

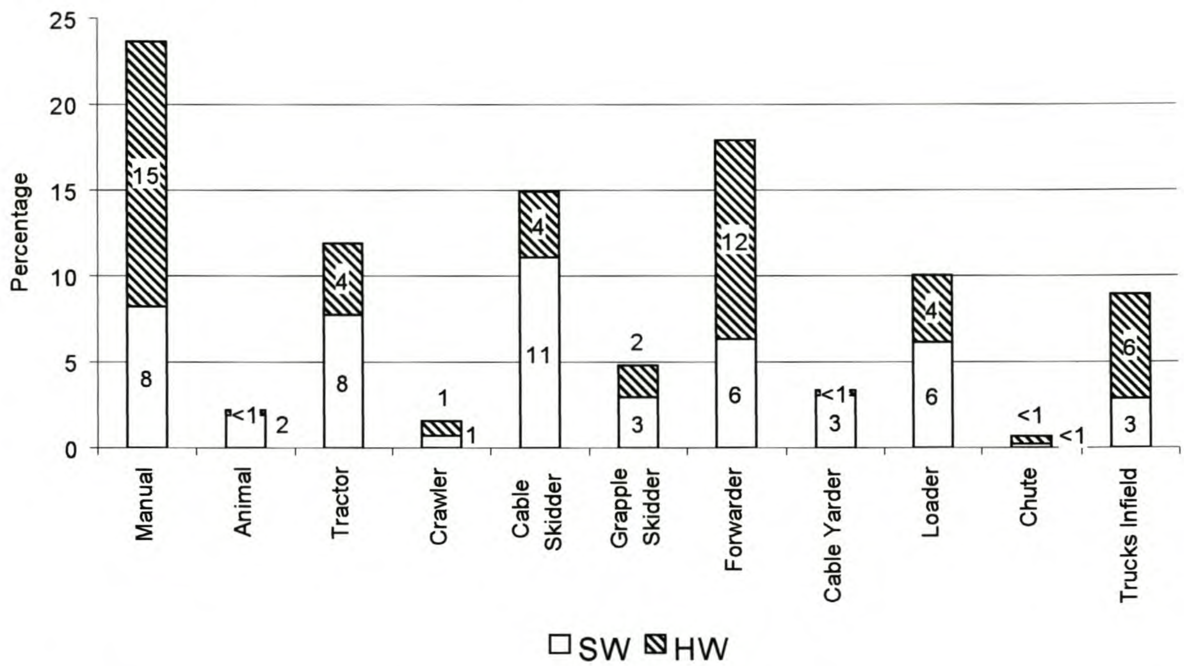


Figure 2.24: Extraction methods: Softwood vs. hardwood

The major volume of the annual cut (23%) is extracted by manual systems (Figure 2.24). This is followed by the skidder (cable and grapple), which extracts 20% of the annual cut (14% softwood and 6% hardwood). Skidders dominate in softwood and own teams are still mostly used (figure 2.25). The forwarder, which includes extraction by tractor and trailer configuration is ranked third and extracts 18% of the total volume (6% of the softwood and 12% of the hardwood is extracted by this means). Trucks are used to remove 9% of the volume infield. This timber is mostly moved to infield extraction routes by 3-wheeled loaders (10% of volume). The 12% extracted by tractor refers to the skidding of tree-lengths to roadside.

Although at least 10% of the afforested area is suitable for cable yarding, only 4% of the timber is currently extracted by this means. Chutes are used on a limited scale

(0,2%) but there is potential for a higher proportion of the annual cut to be extracted by this method.

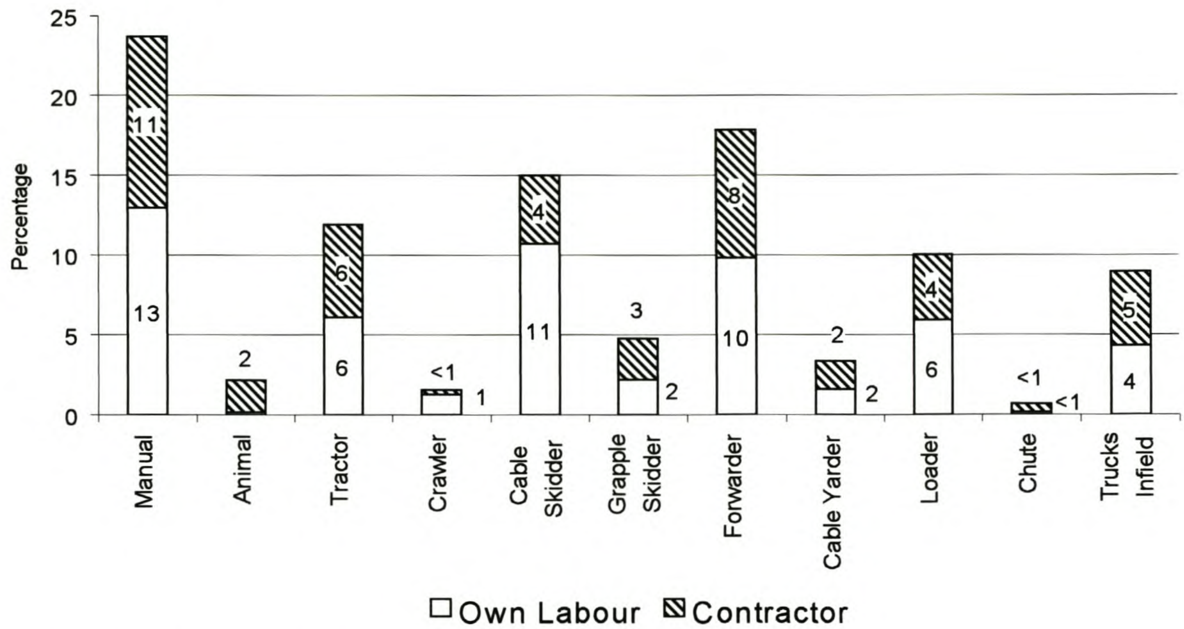


Figure 2.25: Extraction methods: Own labour vs. contractor

Figure 2.26 shows the population of the most important harvesting machines/equipment used in South Africa. The various tractor types (2 x 4 tractors, 4 x 4 tractors, tractors with equal sized wheels) used to extract the timber are given. These highlight the popularity of tractors, with a combined population numbering 577. Of these, 290 are of the 4x4 configuration. Second in popularity to tractors are 3-wheeled loaders, numbering 538, followed by cable skidders at 151. There are 18 grapple skidders in the country, while forwarders total 34.

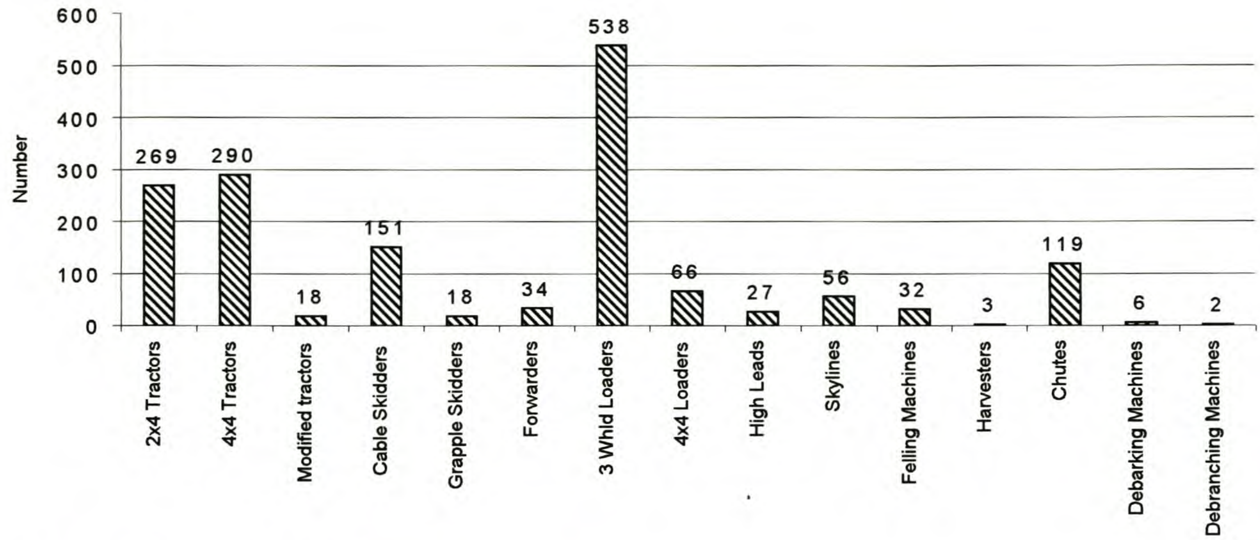


Figure 2.26: Number of harvesting machines

2.3.2.5 Roads and transport statistics

Due to several factors, the South African sawtimber industry uses a tree-length harvesting system for clearfelling of pine stands and the extraction thereof to a landing. These factors are:

- the dimensions of the trees to be harvested;
- the size of branches on pine trees poses difficulties for harvesters to prepare logs;
- the cost of CTLM systems exceeds that of tree-length systems; and
- the skills required to operate high technology machines are insufficient.

Traditionally, sawtimber is sold at forest roadside in South Africa. This was reasonably practical 30-40 years ago, when small volumes of sawtimber were extracted daily by small crawler tractors and animals. These volumes did not congest the forest roads and could be transported to sawmills as and when required. The forestry companies did not focus on the transport of logs in the past and thus the sawmiller became responsible for this function. A conflict of interest is, however, evident in that the grower is responsible for maintaining the roads, while the customer is responsible for transporting the logs over these roads. Lead distances for sawlog transport are much shorter than for pulpwood, as sawmills are generally located fairly close to the timber resource. As harvesting operations are becoming more mechanised, the role of transport is becoming more critical in the value chain. The selection of the most appropriate truck configuration and the constant removal of logs to meet the needs of more demanding customers are important factors which need to be taken into consideration (Brink and Krieg, 2000). Three truck configurations are commonly used for the transport of sawlogs. These are:

- single axle (4x4) units;
- double axle (6x4) trucks; and
- stinger steer, tree-length units.

Pulpwood sales amounted to 9,4 million tons in 1998, 58% of which entered the mills by road, while 42% was transported by rail. Three truck configurations predominate in pulpwood transport. These are:

- truck tractor with 2 semi trailers (interlink);
- truck tractor with 1 semi trailer and drawbar trailer; and
- rigid truck with drawbar trailer.

Morkel (2000) analysed the trends in the use of various configurations. Figure 2.27 depicts these trends.

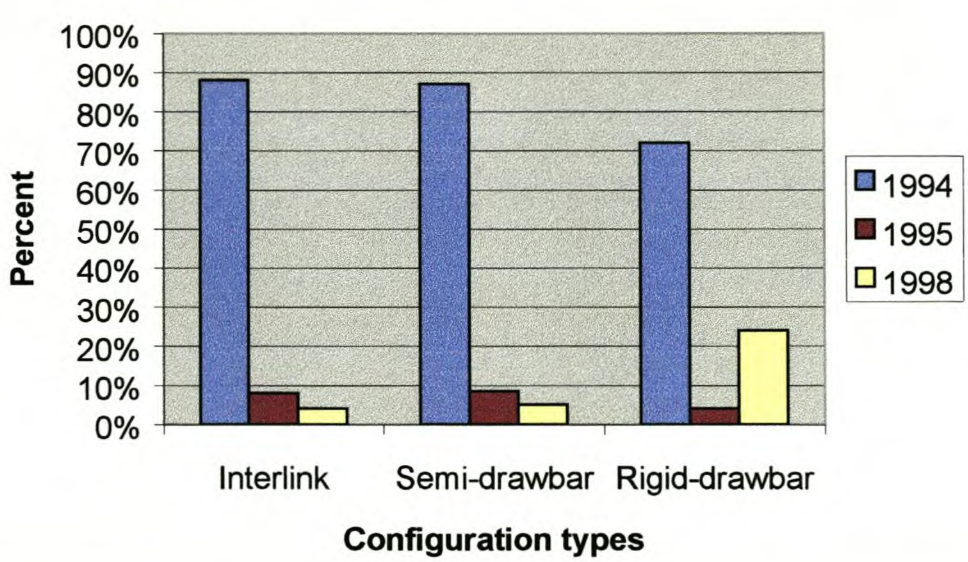


Figure 2.27: Trends for vehicle configurations used in the pulpwood industry (Morkel, 2000)

Interlink configurations dominate, accounting for 76% of the market in 1998. Rigid trucks and drawbar trailers are gaining popularity, moving from 2% in 1994 to 27% in 1998. The reasons for the increase in the use of rigid trucks with drawbar trailers are given below:

- Favourable changes in the road traffic legislation.
- Superiority of tracking, compared to interlinks.
- Better manoeuvrability than with interlinks.

The survey only includes transport vehicles used specifically by the forestry division of companies for delivering logs to a processing plant.

The most popular timber trucks used are 6x4 units, of which 206 are in use. 185 4x2 rigid body trucks follow in popularity. These are traditionally used more for sawlog transport. There are 158 articulated units with a single trailer in use, while 83 interlinks have been recorded. The interlinks are more popular for transporting pulp logs over longer distances.

Similar to the situation for timber transport, many forestry companies and plantation owners prefer not to own road construction equipment but rather hire equipment as and when required or employ contractors to undertake the work. This survey is therefore not able to analyse the total situation. Figure 2.28 only includes road construction vehicles actually owned by forest owners.

Figure 2.29 shows that the most popular vehicle used in road construction operations to be the grader (121) followed by the bulldozer (72) and TLB's (66). 133 tipper trucks are used for transporting road construction materials.

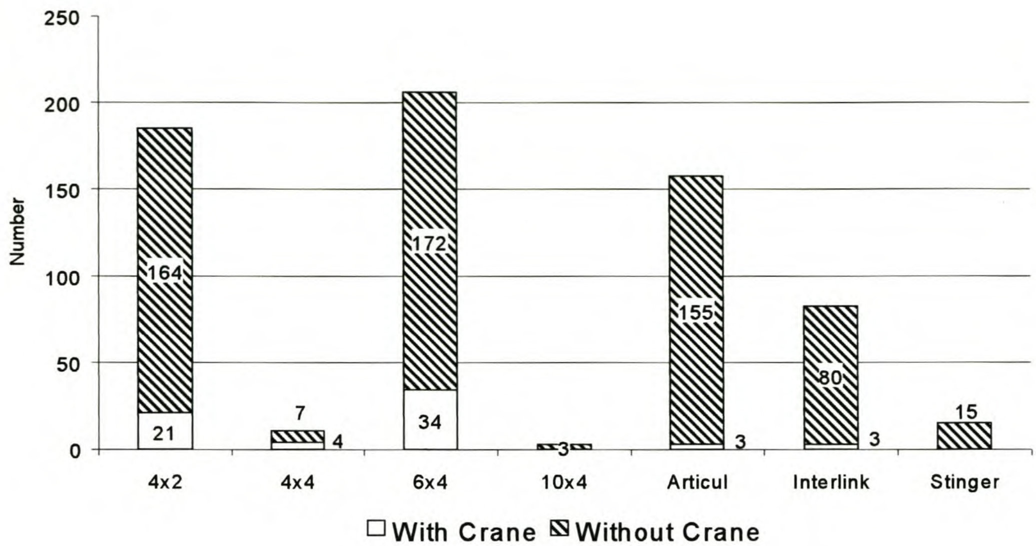


Figure 2.28: Trucks used for timber transport

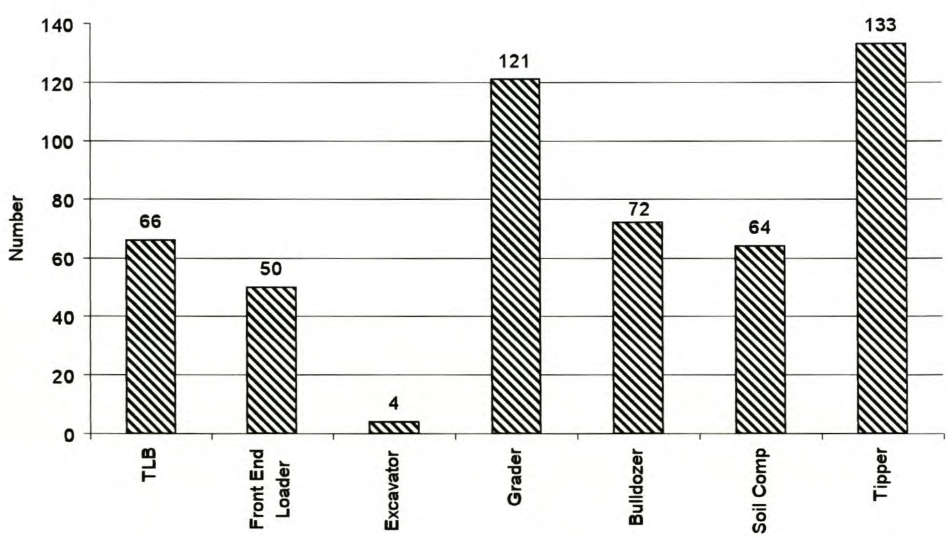


Figure 2.29: Road construction and road maintenance vehicles

Figure 2.30 shows that there are an estimated 92 822 km of plantation roads throughout the country. The categories of roads given in Figure 2.30 are defined as follows:

- Main roads are well constructed, permanently drained, have well maintained surfaces and which are used all year round.

- Secondary roads are relatively well constructed, well drained and usable for most of the year.
- Machine roads are of a low construction standard, used occasionally and not always negotiable. Skid roads are excluded from this category.

Figure 2.30 reflects a rapid road development pattern if one considers that most of the forest development, at least in the private sector, only started 40 to 50 years ago.

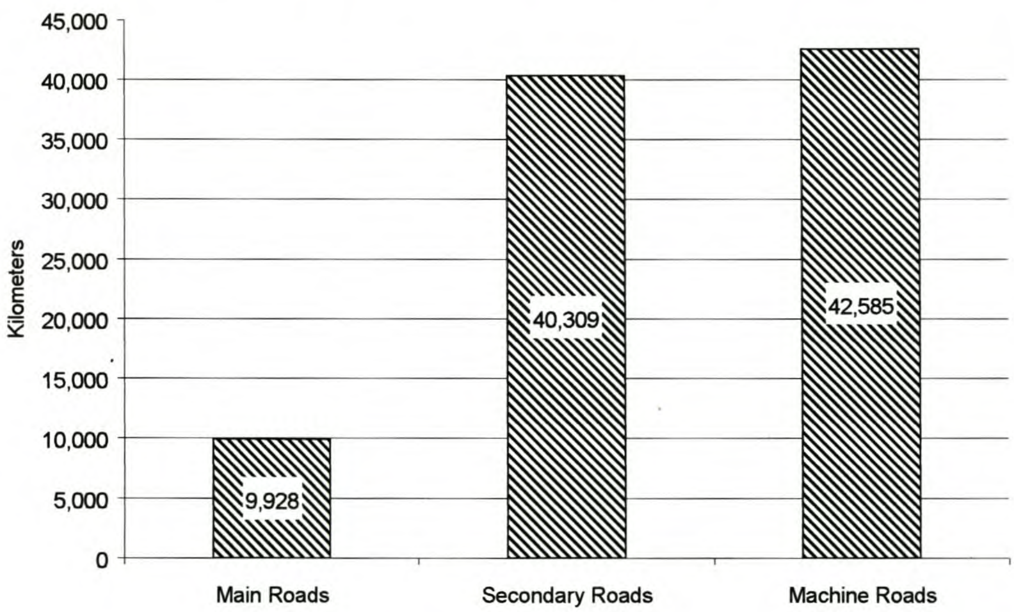


Figure 2.30: Road length in South African plantation forests

2.3.3 Changes between 1987 and 1997 - Comparisons between the two surveys

A comparative analysis is given below regarding the changes between results of the survey conducted in 1987 and those of the one conducted in 1997. The 1987 results are contained in a report prepared for the industry (Warkotsch and Brink, 1988).

2.3.3.1 Harvesting methods

Cut-to-length systems have increased for softwoods and decreased for hardwoods over the past 10 years. Figure 2.31 shows that cut-to-length systems have increased from 44% of total volume harvested to 52%. Softwoods are grown for pine sawtimber and pulp, whilst hardwoods are almost exclusively grown for pulp in short rotation *Eucalyptus* stands. CTL systems for hardwoods have decreased from 89% in 1987 to 77% in 1997. Full tree harvesting systems are virtually non-existent in South African harvesting.

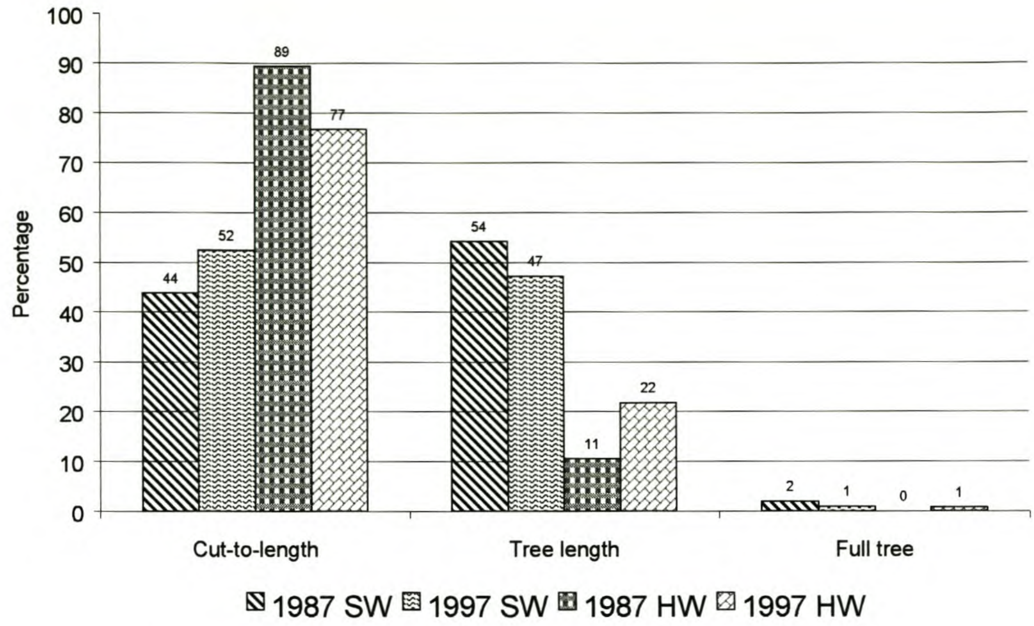


Figure 2.31: Harvesting systems in South Africa (1987 vs. 1997)

Figure 2.32 illustrates the type of equipment used for extraction as well as the volume % age extracted by each type. Figure 2.33 illustrates the number of machines used. There was a significant increase in manual systems, possibly due to the inclusion of the DWAF plantations in the 1997 survey. These plantations were excluded in 1987 as they were then part of the independent states in the previous political dispensation, known as the TBVC states (i.e. Transkei, Boputhatswana, Venda and Ciskei). Should these manual systems be excluded, then tractors and tractor/trailer units have remained unchanged over the last 10 years.

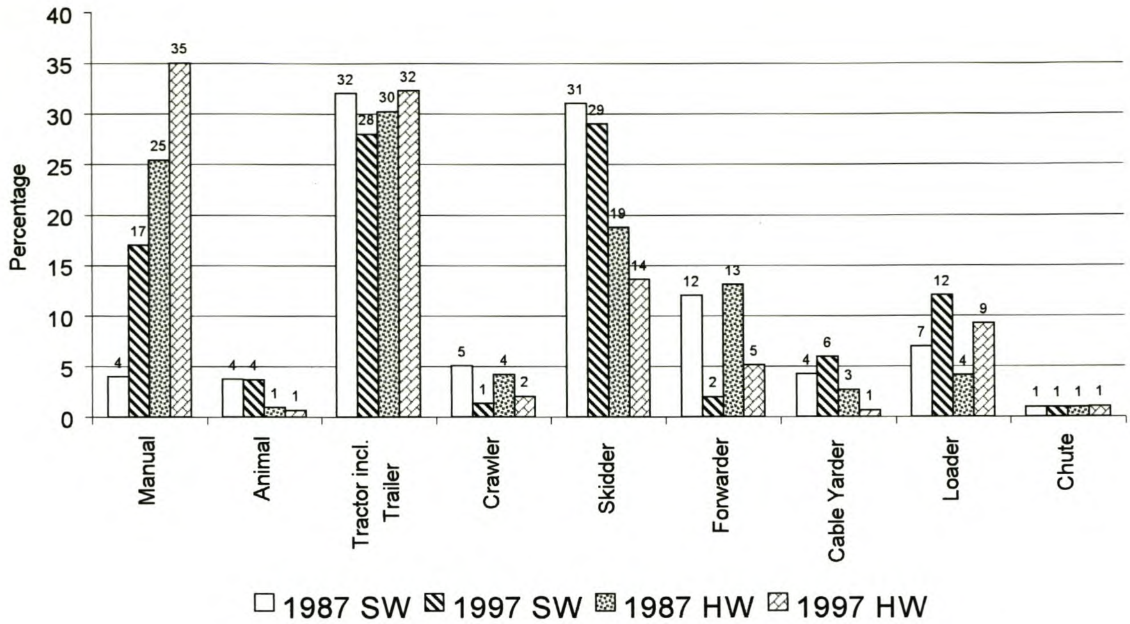


Figure 2.32 Extraction methods used (1987 vs. 1997)

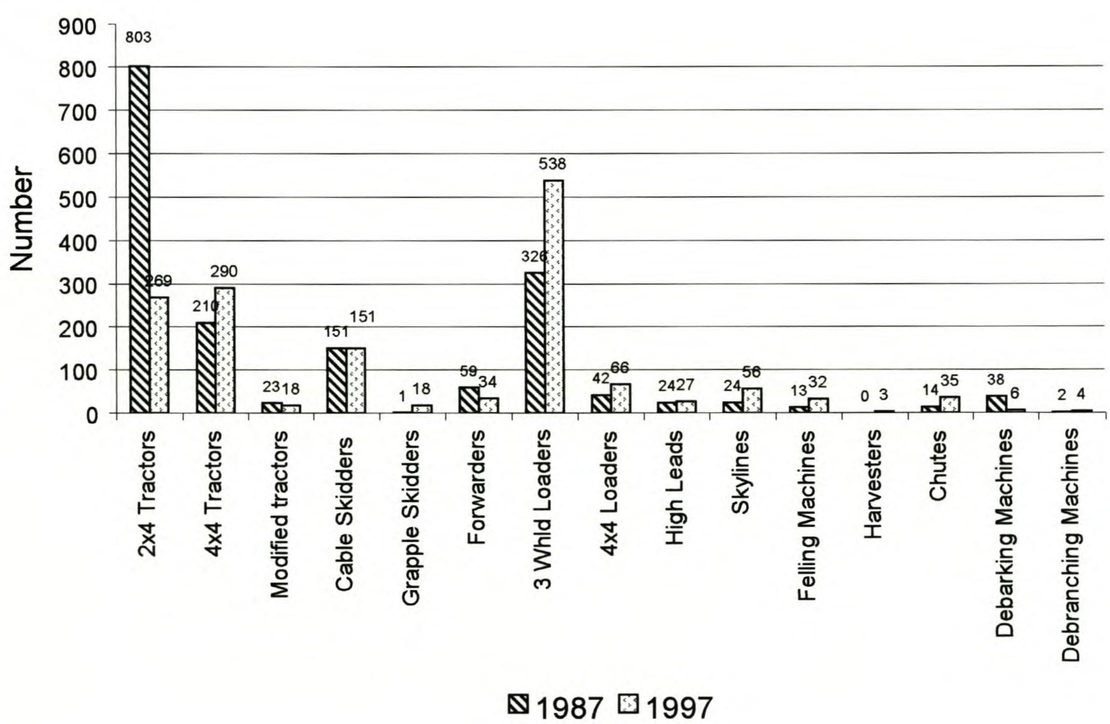


Figure 2.33: Total machine population (1987 vs. 1997)

Animal extraction has also remained virtually unchanged over the last decade, but is insignificant in terms of the total volume harvested in South Africa. For soft- and hardwood extraction by crawler tractor, the percentages have decreased from 5% to 1% and from 4% to 1% respectively. The use of cable yarders has increased over the period for softwoods, but decreased in hardwood harvesting. The number of yarders has however increased from 48 to 83, indicating possible excess capacity. Even though the numbers of chutes used have increased from 14 to 35, the volume extracted has remained unchanged, once again indicating spare capacity.

The use of 3-wheeled loaders has shown significant gains, both in terms of volume extracted, as well as in number. Twelve % of softwoods and 9% of hardwoods were extracted by this method in 1997, while machine numbers increased from 326 in 1987 to 538 in 1997.

The skidder population increased. Cable skidders remained constant, but grapple skidders increased from 1 to 18. The volume extracted by skidder decreased marginally over the period (Figure 2.33).

2.3.3.2 Transport methods

The transport figures only reflect trucks owned or outsourced by the forestry divisions of forestry companies. The figures for processing plants managing their own transport operations are therefore excluded. The use of rigid trucks has decreased at the expense of articulated units and stinger steer type units as shown in Figure 2.34.

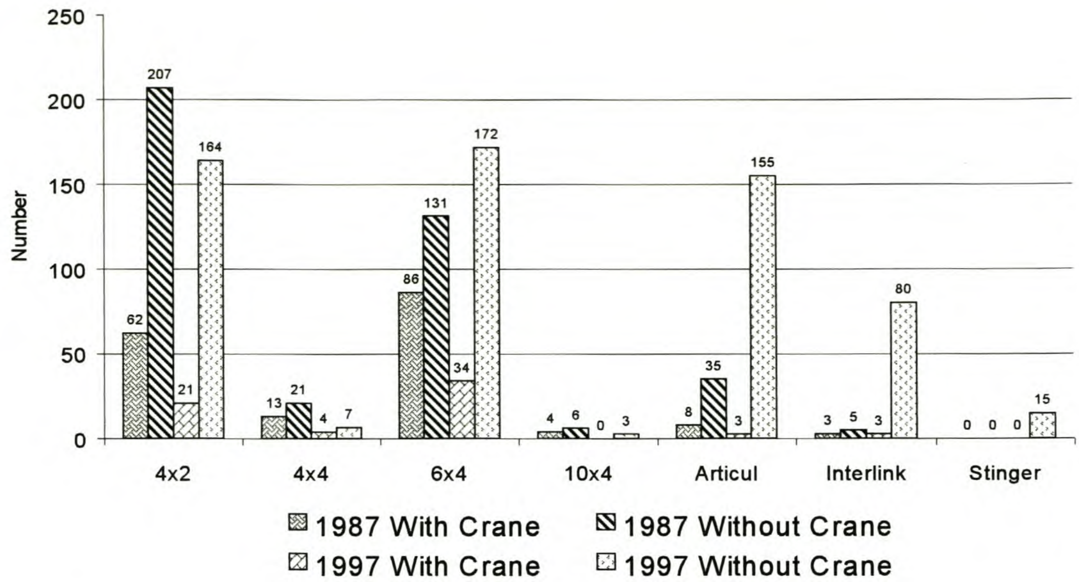


Figure 2.34: Number of trucks in log transport (1987 vs. 1997)

2.4 Comparative analysis of development: South Africa vs. other

Development trends in timber harvesting have, in various countries, been established over a long period, often over 80 years. This allows for the plotting of trends in timber harvesting in various countries over the past century. The data for various regions and countries in the world were obtained by means of a questionnaire, which was also the questionnaire used to conduct the Delphi study discussed in Chapter 5. The reasons for selecting the specific countries and a profile of the respondents are given in Chapter 5. Figure 2.35 reflects the results of the question asked regarding the harvesting developments in these countries and regions. The Figure shows the year of inception of a particular system in a particular country or region.

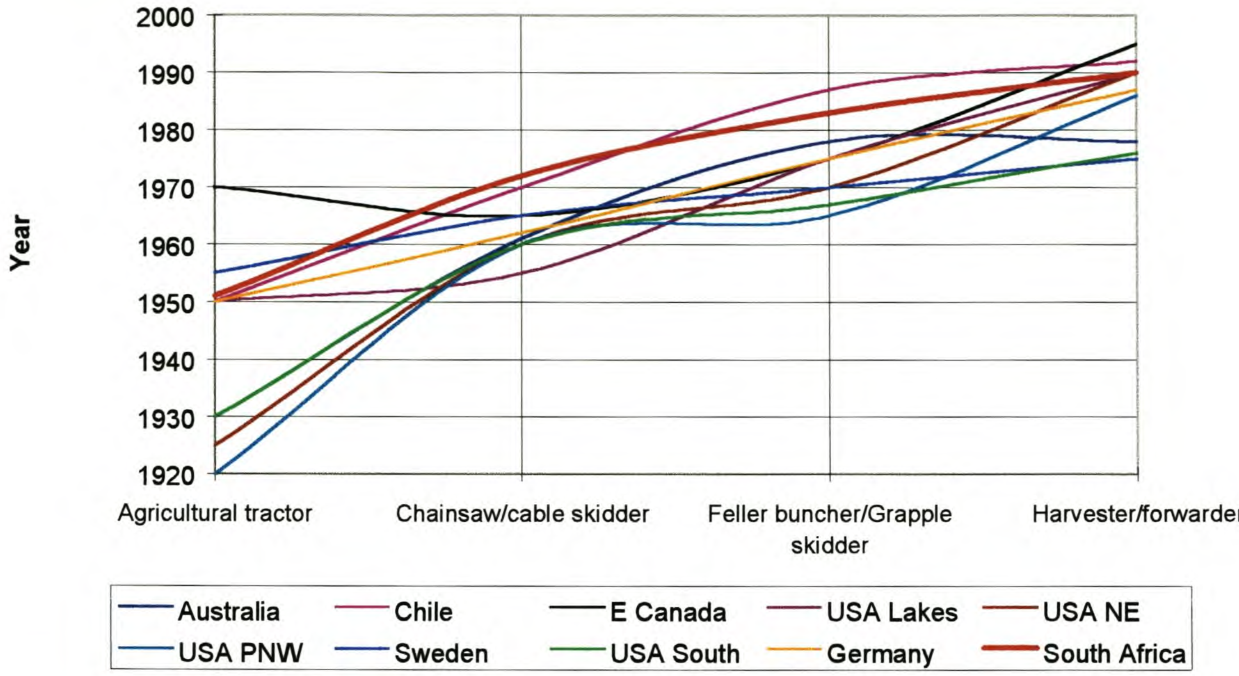


Figure 2.35: Development of harvesting systems over time in various countries/regions

Figure 2.35 shows that the tractor took 50 years to be introduced in all the countries listed. It was first introduced in the Pacific Northwest of the USA in the 1920's and only in 1970 in Eastern Canada. Thereafter there was a convergence in the technology band of the various countries/regions. This indicates that new technologies are becoming more generic across the globe and that differences in harvesting systems from one region to another is more similar than in the past.

Even though the introduction of new technologies in South Africa occurs later than in most countries/regions, it is generally not the last to implement them, with the exception of the cable skidder. This shows that South Africa applied new technology relatively quickly after it became available commercially. It highlights the importance of considering expected future technological developments in harvesting equipment in this study. This is very different to the remainder of Africa, where mechanisation in forestry is virtually non-existent (personal observation).

2.5 Global Forest Engineering developments in the next decade

2.5.1 Global trends in trade of forest products

The overall patterns of production and consumption of wood products are very different between developed and developing countries taken as a group. Developed countries account for approximately 70 % of the total world production and consumption of industrial wood products. Developing countries, on the other hand, produce and consume about 90 % of the world's fuelwood and charcoal, which are the major household energy sources in many of these nations. More fuelwood and charcoal are consumed each year in the world than industrial roundwood. Demand for fuel wood is expected to continue to increase at a rate of about 1.1 % per year between now and 2010, whilst the demand for industrial roundwood is expected to increase at a rate of about 1.7 % per year over the same period. Factors that are expected to influence the industry's ability to meet this increasing demand include increased sources of wood (e.g. plantations and trees outside forests), technological improvements in wood processing (which will increase the efficiency of use of raw material) and the increased use of recovered and non-wood fibre. Trade will continue to assist in balancing wood deficits in one region with surpluses elsewhere.

Growth in the production of tropical forest products has slowed over the past three to five years. The export of most of these products has followed a similar trend; export volumes of tropical logs, sawn wood and wood-based panels having also decreased. Some of the trends reflect major structural changes that are unlikely to be reversed, while others are a response to normal short-term changes in market conditions. Factors influencing the changes include:

- increasing domestic consumption;
- developing producer countries;
- reduced harvest levels because of both environmental concerns and export market conditions;
- a shift in exports from logs, and to a lesser extent sawn wood, towards higher-value products;
- marked reductions in demand in Asia, especially in Japan; and
- whether actions such as eco-labelling and certification affect trade positively or negatively. (FAO, 1999).

From 1996 to 2010, global industrial forest product production and consumption are projected to increase at an annual rate of about 1.7 %, from 1 490 million to 1 870 million cubic metres. Thus, in 2010, output will be about one-quarter higher than it is at present. It will, however, only be about 10 % higher than the peak in production (1 700 million cubic metres) around 1990. Table 2.7 gives a breakdown of supply/demand for Industrial roundwood for 1996 and a forecast for 2010. As is shown, the market for paper and paperboard is expected to have the most rapid growth over this period, at an annual compounded rate of 2,4%.

Table 2.7: Current and forecast global forest production / consumption by product category, 1996 and 2010 (FAO, 1999)

Product	**Production/consumption 1996**	**2010**	**Total growth 1996-2010 %**	**Annual growth 1996-2010 %**
Industrial roundwood (million m^3)	1 490	1 872	26	1.7
Sawn wood (million m^3)	430	501	17	1.1
Wood-based panels (million m^3)	149	180	20	1.4
Pulp (million tons)	179	208	16	1.1
Paper and paperboard (million tons)	284	394	39	2.4

Table 2.8 shows the total forecast production in 2010 compared to the production potential on a regional basis. The comparison is given by region. The figures show that the world production will be within the forecast limits of global production potential. Only Africa will exceed its potential.

Table 2.8: Forecast production of wood and fibre in 2010 and forecast production potential in 2010 (million m³ equivalent) (FAO, 1999)

Region	Forecast Production in 2010		Total	Total potential fibre availability in 2010
	Industrial Roundwood	Recovered and non-wood fibre		
Africa	84	2	86	81
Asia	421	222	643	729
Oceania	54	0	54	80
Europe	502	133	632	893
North & Central America	658	147	805	835
South America	153	2	155	225
World Total	**1 872**	**506**	**2 375**	**2 843**

Growth will vary between regions, with Asia and Oceania likely to show the highest rates of expansion. Slow growth in consumption is expected in Africa and South America, and slow growth in both consumption and production is expected in North and Central America. North and Central America will, however, remain by far the largest producing and exporting regions in the world. Europe, Asia and North and Central America will account for about 85 % of production and over 90 % of consumption in 2010 (roughly the same share as in 1996). However, within this group it is expected that a small share (about 5 %) of global consumption will be gained over the period by Asia at the expense of North and Central America.

Asia will continue to be the world's only net roundwood and product importing region. In terms of gross trade flows, however, trading patterns are not expected to change, but the shape and form of trade will continue to do so. Since the 1950's, trade in forest products has steadily increased as a proportion of total production. The outlook is for more trade, both in gross volumes and as a proportion of production.

Increases in trade are predicted for two reasons. Firstly, many countries are expected to continue to give priority to developing manufacturing and processing capability rather than exporting roundwood and pulp. This will prompt continued declines in exports of semi-processed products as producers seek to add value to their raw material. For example, a greater proportion of commodities such as sawn wood and panels will be processed further into furniture and joinery products. Secondly, an expansion of domestic markets is expected as developing countries' economies grow and mature. Maturing of these markets will give rise to economies of scale in processing, product design, assembly, manufacture and distribution. The increasing specialisation, market segmentation and competition will promote higher levels of trade, both within regions themselves and internationally.

On the supply side, the factors leading to greater production of both roundwood and products in the future will differ widely among countries. In some countries, roundwood production will be increased by supply-driven factors, such as the opening-up of new areas of forest and the maturation of extensive plantation resources (e.g. in countries around the southern Pacific Rim). However, more typically, production will be increased by increased demand because of high rates of economic growth (e.g. in most European and many Asian economies). In countries where there is considerable demand, and particularly where forest resources are limited, wood product producers will consider using a broader range of wood and non-wood fibre raw materials than they have in the past (FAO, 1999).

2.5.2 Environmentally sound timber harvesting

Howard (1994) refers to a new paradigm that is required in the approach to harvesting in North America. He believes that the essence thereof will be the maintenance of biodiversity. This is confirmed by Lackey (1994), who is convinced that biodiversity should have the balance of power when it comes to forestland use decisions. A requirement for the widespread adoption of environmentally sound timber harvesting technologies is the demonstration that such operations can be economically feasible, environmentally sound and socially acceptable. In response to this need, case studies have been undertaken in tropical forests in the Congo, Brazil and Indonesia to test some of the applications suggested in the FAO Model Code of Forest Harvesting Practices, published in 1996 (FAO, 1996).

These studies have found that:

- environmentally sound timber harvesting is not necessarily more expensive than traditional timber harvesting methods;
- use of the environmentally sound practices reduced damage to standing stock by as much as 60 % relative to traditional harvesting methods;
- appropriate pre-harvest planning reduced the area of forest roads, skid trails and landings considerably (from 20 to 4.5 % in the study in Brazil);
- disturbance of the canopy was reduced from 25 to 11 %; and
- total timber loss was reduced by more than 30 % .

These findings correlate well with the expectations for reduced-impact harvesting of forests in Indonesia, as stated in the (CIFOR) guidelines. The endorsed practices were expected to:

- reduce disturbances to soil and residual vegetation by at least 50 % in comparison with conventional logging operations where the guidelines are not applied;
- limit overall direct impacts to the forest to less than 25 %;
- conserve wildlife and other forest resources, including non-wood forest products, threatened and endangered species, keystone plant resources and water;
- diminish direct logging costs by at least 15 %; and
- protect the long-term integrity and value of the permanent forest estate.

Environmentally sound harvesting is a very broad term, as demonstrated by Ray *et al.* (1994), who includes visual quality as a factor that needs to be considered. The art lies in finding a balance between economics and social pressure. Weyerhaeuser Company in the USA now includes aesthetics as part of the resource planning process in harvesting operations (Larkoski *et al.*, 1994). The inclusion of biodiversity issues in harvesting operations has also been confirmed by Weinberger (1994) and Howe (1994).

Achievements in environmentally sound road construction, using hydraulic excavators and advanced blasting techniques, have been thoroughly documented by recent case studies in Austria and Bhutan. The advantages of central tyre inflation (CTI) have been exploited to a significant degree in many forestry countries (Brink, 1995; Brink, 1996; Brink 1997, Brink 1998). The prolonged hauling ability of log trucks fitted with CTI during periods of reduced bearing capacity of forest roads have been the major contributor to the use of CTI.

Research started focusing on environmental issues in harvesting in the late 1980's. Myhrman (1993; 1997) discusses factors being researched by Skogsforsk. These included factors such as engine emission levels, the use of synthetic oils, and the reduction of soil compaction by using soft footprint tyres, CTI and improved vehicle geometry. The focus on these research issues is increasing steadily throughout the world when considering the work being conducted by institutions like FERIC (Canada), Skogsforsk (Sweden) and Forest Research (New Zealand).

To meet the demand for wood and non-wood products, while simultaneously fulfilling the demands for environmental and social services from forests, is the future challenge facing the forestry sector. Efforts to find an acceptable balance between production and protection and between use and conservation drive much of the debate surrounding the forestry sector today.

2.5.3 Changes in timber harvesting systems

a) *Machine technology*

Buys (2000) identified six generic global trends:

- Globalisation.
- Totally managed environment.
- "Smart" products.
- Increasing pace of technological development.
- Specialisation in technical areas.
- Customisation for specific niche markets.

These trends have relevance to Forest Engineering when considering the type of equipment, which will be developed in the future. Guimier (1998) describes technology advances in equipment as follows:

The machines of the future will be equipped with "intelligent" control systems that let them adapt to the environment in which they are working. By using various sensors, the machine will "know" when it is on a slope, when it is on wet ground, or when its wheels are slipping.
Thor (1998) claims that current mechanised systems will continue to be automated to the point where robots could be used for harvesting operations. The sophistication of the equipment could require operators similar to fighter pilots.

Because of automating machine functions, operators could concentrate their energy and resources on making strategic decisions rather than on routine operating tasks. After an initial learning phase, the machine would manage systematic and repetitive actions by itself; these could include placing logs in piles, grabbing a tree for delimbing, or moving in a straight line. Guimer (1991) referred to the revolutionising of harvesting equipment through the introduction of robotics, artificial vision, process controls and automatic measuring devices. Two examples of advancements in machine technology are the walking machine, designed by Plustech in Finland, and the Japanese designed Tri-Track mover. The walking machine is probably the most sophisticated harvesting machine ever built, even though the idea of a walking machine is not new. An earlier version was the three-legged Menzie Muck, which appeared in Switzerland in the 1970's. However, because its movement was operator controlled, it was slow and cumbersome and thus disappeared off the market (Drushka and Konttinen, 1997). These technology developments are discussed in more detail in Chapter 5.

The weight of components in forestry machines is also continuously being reduced. The two main reasons for this are to increase their payload or capacity and to reduce ground pressure as much as possible, thus reducing the impact on the soil.

Global positioning systems (GPS) technology now permits users to rapidly update maps and other forestry data, and efficiently perform on-site surveys, which formerly required considerable time and resources. Harvesters in Sweden have been equipped with GPS receivers, which allow them to monitor thinning intensities (Thor, 1998).

Most future equipment will incorporate some form of machine vision that will let it evaluate the objects it must handle (e.g. trees, logs, chips) so as to respond appropriately. For example, FERIC foresees the development of a camera system for measuring logs handled by delimbers or processors. Analysing these materials will help to optimise processing, as in the case of accurately determining stem diameters and lengths to improve slashing. The same technology will be developed for measuring logs (while accounting for various deductions for rot), as well as for the analysis and sorting of pulp chips.

The consequences of machine vision, will have the greatest potential impact on optimal fibre utilisation from plantations. The New Zealand industry is currently exploiting this opportunity by compromising on machine vision by combining computer optimisation with visual human input. Although a great deal of work has been done over the last 20 years on optimal log scaling by using hand-held computers, New Zealand is the first country to implement the concept on an industry-wide basis. Within five years, about 50% of the national annual cut in New Zealand can be expected to be scaled with hand-held computers attached to electronic callipers (Brink and Conradie, 1998). Longer-term research is also being conducted in New Zealand where a tool is being developed that can be positioned as part of the processing system that provides real time intelligence into the manufacturing process, itself leading to optimal processing and segmentation of material into groupings of identical performance. (Lane *et al.*, 1998, Burton, 1998). However, this technology will take a significant period to be adapted to harvesters working in the forest.

Even though airship technology has been investigated in Canada in the past, Parker (1998) believes that as environmental pressures increase in timber harvesting, airships can be used to reduce the forest road network by moving in harvesting machinery and transporting logs out to the nearest road or railhead. Helicopter logging has been used for many years to access timber in remote areas and to salvage burnt timber, particularly in North America. Heli-logging trials have been conducted in North America and Europe since the late 1950's (Taylor, 1976).

b) Harvest planning

As the sophistication levels of equipment increase, there will be a greater need to focus on sound harvest planning procedures. This will be necessary at both tactical and operational level (Brink and Kellogg, 2000). A critical requirement for the effective application of advanced technology capable of reducing environmental impacts associated with harvesting, is a well-designed and continuous programme of training for the harvesting teams, their supervisors and the persons responsible for harvest planning. Sound planning techniques are reflected in the refinement of equipment selection, which incorporates all relevant factors. One such document was prepared by FERIC in 1999 (MacDonald, 1999).

c) Outsourcing

Outsourcing has played an increasingly dominant role in forestry over the past decades. Not only has there been an increase in the contracting out of operations (personal observation), but there has been an increase in the size of the contracts awarded in some parts of the world. Galbraith (1998) describes the trend in New Zealand, where all levels of management, up to corporate level, are being outsourced. The objective of the "key supplier" trend in New Zealand is to change the relationship between companies and its contractors; moving from a large number of small closely managed contract production units, to a smaller number of key suppliers of services with full responsibility for managing their own operations. A case in point is the forestry company Carter Holt Harvey, which has moved from using over 200 contractors to less than 40 key suppliers over the last few years. The reason for the change is to reduce unit costs, increase performance capability and to reduce in-house management overheads (Brand, 1998). This trend is also confirmed by Thor (1998).

d) Changes in human resource (HR) management

Smith (1998) lists the following recommendations for sound HR management in a rapidly changing environment:

- Organisations will need to demonstrate their concern for equity and equality among all their employees.
- Organisations will need to develop the work lives and careers of their employees by providing opportunities for development and continual learning.
- Organisations will need to develop and implement policies that demonstrate their social and environmental responsibility.

When considering the increased level of sophistication of future harvesting machines, organisations will have to develop the necessary strategies to recruit, select and keep the appropriate human resources within the industry. As Thor (1998) explains – it makes sense to leave the routine tasks to the machine (positioning and processing) and allow the operator to concentrate on fewer, activities that are more complex. This will require smart technology, with smart people working in smart organisations. Guimer (1991) believes that safety issues and ergonomics will be of vital importance in future harvesting systems.

2.5.4 Changes in transport

The key to efficient log transport lies in a well-developed road network (Andersson, 1997). A huge portion of the costs in the value chain lie in log transport – between 30% and 70%, depending on road conditions and lead distances. It is thus imperative to discuss developments in log transport – albeit it briefly. The changes in transport systems have focused a great deal on the improvement of componentry and engine technology in order to reduce fuel consumption and increase payload (Wilshier, 1998). Some of these changes are described below:

- *Air suspension.* Although air suspension systems are more expensive to fit than conventional systems, they have a significantly lower maintenance cost. A trailer costs some 10-15% more to construct with air suspension (Wilshier, 1998) but this is offset by lower maintenance requirements and hence lower maintenance costs.
- *Alloy hubs.* Alloy hubs are common throughout the world today and is continually replacing steel hubs. Their major advantage lies in the reduction of tare weight.

- *Axle design.* Significant improvements in axle design have occurred over the last few years, specifically with regard to extended life and the lowering of the centre of gravity. Lubrication maintenance is also improving on axle units.
- *Central Tyre Inflation (CTI).* CTI has been discussed earlier. In summary, CTI has the following benefits:

  - reduced road maintenance cost;
  - the use of log trucks on steeper longitudinal grades;
  - improved driver comfort;
  - reduced tyre cost; and
  - reduced fuel consumption.

  CTI is still in its infancy in forestry, but will become the established norm across the world in the next decade.
- *Onboard computers.* As with CTI, onboard computers make a significant contribution to sound fleet management, if the system is correctly used. The major benefits of onboard computers are a reduction in operating costs and an improvement in driving standards. The use of onboard computers will continue to expand as the technology becomes increasingly simple to use and more robust in the harsh forestry environment (Wilshier, 1998).

2.6 Forecasting variables

The discussion related to the developments in Forest Engineering serves as a foundation in identifying key variables that need to be forecast. These are summarised below:

- trends in fuel cost,
- labour cost trends,
- trends of the past developments of specific machine types,
- substitution trends: CTLM vs. TL machines,
- technological developmental trends,
- identification of change drivers in the Forest Engineering value chain, and
- identification of appropriate financial evaluation methods,

These variables will be used to identify the appropriate forecasting techniques, which are relevant to addressing these variables in a forecast. This is addressed in Chapter 3.

2.7 Conclusion

This Chapter has given an overview of the developments of Forest Engineering, both globally and locally. It is evident from the Chapter that technological developments in Forest Engineering are a key change driver.

Considering that we are living in a rapidly changing world and that any form of forecasting will be affected by the pace of change, it is necessary to gain an understanding of technology and its effect on change. This is dealt with in Chapter 3. After discussing technology, the Chapter proceeds to evaluate various forecasting methods and the suitability thereof with regard to the development of a forecasting method for the Forest Engineering value chain.

3. TECHNOLOGY AND FORECASTING

3.1 Introduction

After the overview given in Chapter 2, it is evident that Forest Engineering is technology-driven. Traditional Forest Engineering courses include very little on technology, its development and how to forecast this development. For this reason it is necessary to give a comprehensive overview of the subject. Chapter 3 commences with an overview of technology and how it is to be managed. It includes innovation, waves and cycles in technology and the management of technology strategies within industries and organisations. This background information is critically important to allow for a sound understanding of what is to be considered when selecting forecasting techniques and how an industry or organisation should manage towards the expected future outcomes. Without an implementation strategy, the forecast loses most of its value.

Chapter 3 then proceeds to evaluate various forecasting techniques and their relevance to Forest Engineering. After discussing each technique, a short conclusion is given as to how the technique could be included in the development of a forecasting methodology. Only those techniques, which are believed to be of relevance, are included in the chapter. The reasons why these techniques were selected are given in table 3.2.

Finally, the Chapter concludes with a discussion of approaches to the costing of the Forest Engineering value chain. These techniques are limited to Discounted Cash Flow (DCF) techniques and those used in traditional machine cost calculations (MCC). This is required to select the most appropriate method of selecting the preferred value chain for the future.

3.2 Technology

3.2.1 Definitions of technology

Berry and Taggart (1994) define technology as: “the systematic application of scientific or other organised knowledge to practical tasks”.

Monck *et al.,* (1988) views technology as follows: "Technology is both a body of knowledge concerned with the solution of practical problems – what we might term "know-how" – and the tools and artefacts which are used to achieve those solutions: it is both the software and hardware".

Morris (1985) has the following definition:

- "The application of science, especially to industrial or commercial objectives.
- The entire body of methods and materials used to achieve such objectives".

The historical derivation of the term *technical* comes from the Greek word *technikos*, meaning "of art, skilful, practical." The *ology* portion of the word indicates a "knowledge of" or a "systematic treatment of". Thus, the derivation of the term technology is literally "knowledge of the skilful and practical". Technology can therefore be defined as the knowledge of the manipulation of nature for human purposes.

The term *science* is derived from the Latin *scientia*, meaning "knowledge". However, the modern concept of scientific research has come to indicate a specific approach toward knowledge - one oriented towards nature that results in discovery and in explanations of nature. Science can therefore be defined as the discovery and explanation of nature.

The link between science and technology is engineering. Engineering is the understanding of and manipulation of nature for human purposes.

In these definitions, one should first note that science is not focused by human purposes, as are engineering and technology. Science though, remains relevant to human purpose, but is focused by the ubiquity and generality of the existence of nature.

Although research activities in science focus primarily on discovery and understanding, sometimes inventions do occur in scientific research (notably instrument, technique or materials inventions). When inventions do occur in basic science, they are usually the basis for radically new technologies (such as the laser or the transistor). Engineering differs from technology by focusing on combining the technical knowledge of how to manipulate nature with scientific explanations of nature as to how and why the manipulation works.

Although technologically focused research concentrates on inventions and their development toward products, considerable levels of research effort in the engineering disciplines (in addition to the scientific disciplines) are also focused on advancing the understanding of nature. Such research has also been called engineering science. The better engineers understand nature, the more and clearer ideas they may have for refining its manipulation. The importance of understanding the relationships between science, technology, and engineering is that research for radical innovation, both basic new technologies and next generations of technologies, requires advancing the underlying scientific base (Betz, 1993).

3.2.2 Technology and change

Porter (1990) regards technology as the key determinant of industrial regeneration. There is, however, a major paradox regarding technology development. While markets are becoming global in nature, according to him, technology development remains confined to local clusters of innovation in a variety of global locations.

Pursuing further scientific understanding of the phenomenon on which a radical innovation is based provides a fertile area for improving the technology. The modern world of technology innovation involves ties between industrial and academic researchers (Betz, 1993).

Bright (1963) states that technological change is the most powerful factor in the business environment and that its power appears to be growing. Technological change is impressive not only for its variety but also for its "chain reaction" of effects on industry and society. He describes the example where the missile reduced aircraft manufacturing employment to less than one-third of the number originally employed within six to eight years. However, it created literally thousands of new suppliers involved in advanced technical specialities. It shifted the location of employment, upgraded the manufacturing skills required, changed the educational background needed by designers, required different plant facilities, processes, and new service activities. It created high demand for new power sources, fuels, materials, control systems, and test instrumentation. A basic and applied research activity resulted, which was in itself larger than most traditional industries. Meanwhile, the missile is indirectly reducing many activities required to support the traditional form, quantity, and operation of military aircraft.

Rothwell and Zegveld (1985) identified 3 key factors that have fuelled a growing interest in technology management:

a) Technology explosion

They estimated that 90% of all available technical knowledge was generated during the last 55 years; and that of all the scientists and engineers who ever lived, 90% are living and working now. As a result, our technical knowledge will continue to increase exponentially, doubling probably every 30 years. This is confirmed by Buys (2000), who says that the increasing pace of technological development is a global trend.

b) Shortening of the technology cycle

The traditional technology cycle starts with a scientific discovery and ends with the diffusion in the marketplace of products and processes embodying the new technology. These cycles have become steadily attenuated, leading to a constantly increasing demand for innovation in products and services.

c) Globalisation of technology

The more technologically advanced developed economies such as the United States and Europe are rapidly losing their dominance in generating new technologies. Countries in the Pacific Rim – notably Japan, South Korea and Taiwan – have shown that they can synthesise new technology faster into new products and processes than the United States or Europe. Transfer of technology between countries is continuing at an ever-increasing pace, regardless of barriers and controls. In essence, technology is becoming a global resource. The dynamics of technology are therefore changing, as summarised by Perrino and Tipping (1989). The pace of technology is accelerating, raising the stakes and risks for managing innovation, and requiring early warning and shorter response time to capture opportunities. Specialisation and systems requirements are both increasing, driving a growing need for interfacing people and disciplines, and integrating critical skills from wherever available. Newer technologies are rapidly becoming pervasive, redefining competitive value-added activities across a broad range of traditional markets and spawning major new growth markets.

Nearly forty years ago, Bright (1963) identified seven trends, which he believed would drive technological change. These factors continue to be of importance today, highlighting the accuracy of his work:

a) Transportation

It begins with man's increasing mastery of distance. The fundamental result of the progress in this respect is that geographical features of the earth have lost most of their traditional significance. Increasingly, only man-made regulations will provide limitations; geographical features and transportation cost and time will not. An important result of more travel is the rapid and widespread exchange of cultural, economic, political, and technological ideas. It is becoming easier to transpose ideas from one location to another. It will be harder to keep ideas, concepts, and procedures secure and isolated from the rest of the world.

b) Energy

The present number of alternatives available to mankind in terms of fuel sources, methods of generating electrical power, forms of transporting energy, and modes of application and control has never existed before. The more one studies technical progress in energy, the more exciting the opportunities for traditional businesses appear to be.

c) Organic and inorganic life

A general consequence of altering organic growth is an increase in the economic value per unit of production. This tends to lead to reduced cost per unit of output. However, this progress requires two things: (i) mechanisation and (ii) scientific farming based on proper soil and food conditioning. It seems as though there will be less and less opportunity for the small producer to afford or supply these technical and economic outputs.

d) Characteristics of materials

There is very little security for many raw materials in their traditional markets. Suppliers and processors of raw materials can expect the competition between materials to be increasingly severe. Simultaneously, new markets for traditional materials are opening up as technology enables the characteristics of the materials to be modified for new purposes or as it provides ingenious combinations with other materials to serve special needs. This intense competition across material lines suggests that the value of some raw material assets will be altered substantially unless the present suppliers and processors reduce prices or provide technological advances in their physical characteristics. A growing product specialisation is inevitable, and with it comes a multiplicity of product lines by material suppliers. The selling effort must and will become far more technical, because materials salesmen will have to translate their customer's special needs into product opportunities and applications.

e) Sensory capabilities

There has been a notable extension of man's sensory capabilities. We can see, hear, or otherwise identify conditions far beyond the range of human eyesight or hearing, and thus operate under conditions that previously prohibited or limited performance. In addition, there is growing power to do something about a distant activity by remote control. To extend these sensing and control capabilities new industries have arisen. Instrumentation and control systems are among the most important growth activities.

f) Mechanisation - physical

Usually there is a substantial reduction in the labour content per unit produced. On the other hand, the automation equipment builders have increased manpower to produce the equipment, although probably not proportionally to the labour saved by their equipment output. There is evidence that many of the skilled operator jobs are eliminated or simplified by highly automatic equipment yet many unskilled jobs are also mechanised out of existence. To the extent that the equipment content is greatly increased or is unique and novel, a larger and more skilful maintenance force may be required. Thus, the net effect on factory work forces is not generally predictable, other than to say that in some instances it is severe and in others moderate.

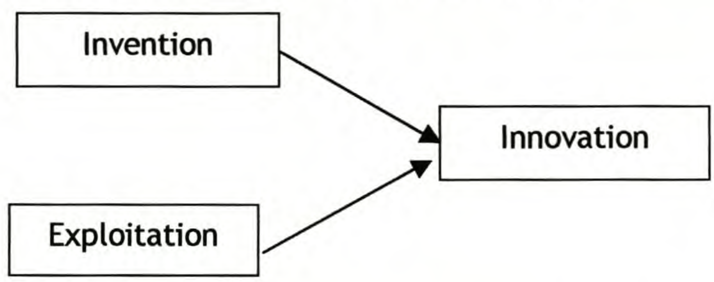
g) Mechanisation - intellectual

The ultimate impact can hardly be visualised yet. In each case, one of the important consequences is the reduction in time required to perform the activity, and a second, an improvement in accuracy and thoroughness. Mechanising intellectual processes, once the programme is established, greatly reduces set-up time and improves accuracy over human performance. An unsettled question is the effect on workforce skill. The skills needed in many parts of intellectual tasks certainly are reduced. However, the skill needed to analyse and programme the problem for computer action has increased. We can anticipate that the mathematical competence needed at managerial and staff levels will rise.

Unquestionably, the era of dynamic business change is based on technological progress. In this mercurial environment, traditional products, materials, skills, and production facilities are made obsolete in a few years and, in some cases, a few months. At the same time, new scientific discoveries and achievements in technology offer opportunities equally great. The calls for new technological advances seem endless. Thousands of businesses are going to rise or fall on the ability of their managers to respond effectively. These new demands do not present themselves nicely at the doors of obsolete businesses, nor do potential disrupting innovations announce their birth with trumpets.

3.2.3 Invention and innovation

Roberts (1988), describes innovation in the following terms:



Innovation is composed of two parts; firstly the generation of an idea or invention, and secondly the conversion of that invention into a business or other useful application. Using the generally accepted (broad) definition of innovation – all of the stages from the technical invention to final commercialisation – the technical contribution does not have a dominant position. To summarise: *Innovation = Invention + Exploitation.*

The process of innovation is defined by Norton and Bass (1992) as the development and implementation of new ideas by people, who over time, engage in transactions with others within an institutional context. This definition is sufficiently general to apply to a wide variety of technical, product, process, and administrative types of innovations.

Van der Ven (1986) describes an innovation as a new *idea,* which may be a recombination of old ideas, a scheme that challenges the present order, a formula, or a unique approach which is perceived as new by the individuals involved. As long as the idea is perceived as new to the people involved, it is an "innovation," even though it may appear to others to be an "imitation" of something that exists elsewhere.

Freeman (1982) distinguishes between innovation and technological innovation. He says that strictly speaking, technology is simply a body of knowledge about techniques, as the word itself implies. Nevertheless, it is frequently used to encompass both the knowledge itself and the tangible embodiment of that knowledge in an operating system using physical production equipment. "Technical innovation", or simply "innovation", is used to describe the introduction and spread of new and improved products and processes in the economy and "technological innovation", to describe advances in knowledge.

Drucker (1985) believes that as managers recognise the heightened importance of innovation to competitive success, they face an apparent paradox; the orderly and predictable decisions on which a business rests depend increasingly on the disorderly and unpredictable process of innovation. He continues further to say what all successful entrepreneurs have in common is not a certain kind of personality but a commitment to the systematic practice of innovation.

The overall management of technological innovation thus includes the organisation and direction of human and capital resources toward effectively:

- creating new knowledge;
- generating technical ideas aimed at new and enhanced products, manufacturing processes and services;
- developing those ideas into working prototypes; and
- transferring them into manufacturing, distribution and use (Roberts 1988). An invention or creative idea does not become an innovation until it is implemented or institutionalised.

3.2.4 The management of technological innovation

Van der Ven (1986) found that of all the issues surfacing in his meetings with over 30 chief executive officers of public and private firms, the management of innovation was reported as their most central concern in managing their enterprises in the 1980's. Increasingly, corporate strategists are making a more precise distinction between "technology" and "technology management". Technology addresses the application of scientific and engineering knowledge to the solution of problems. Technology management, however, has a broader charter; the integration of technology throughout the organisation as a source of sustainable competitive advantage (Werther *et al.,* 1994). Betz (1993) emphasises that historically, the companies that participated in the early stages of a radically new technology have often been the firms that built strong and large organisations to exploit the new products of and new markets for the new technology.

Technologically innovative outcomes come in many forms; incremental or radical in degree; modifications of existing entities or entirely new entities; embodied in products, processes or services; oriented toward consumer, industrial or governmental use; based on various single or multiple technologies. Whereas invention is marked by discovery or a state of new existence, usually in the laboratory or on the bench, innovation is marked by first use, in manufacturing or in a market (Roberts 1988). Most innovations, especially the successful ones, result from a conscious, purposeful search for innovation opportunities, which are found only in a few situations.

Drucker (1985) identifies the areas of opportunity for innovation, which exist within a company or industry:

a) Unexpected occurrences

Unexpected successes and failures are such productive sources of innovation because most businesses dismiss them, disregard them and even resent them. When IBM produced the first modern accounting machine for banks in the early thirties, the banks did not want them. What saved the company was the need for such a machine by the New York Public Library. IBM went on to become the leader in computer technology for many years.

b) Incongruities

One source of incongruity is between economic realities. For example, when an industry has a steadily growing market, but falling profit margins, an incongruity exists. This happened to the steel industry between 1950 and 1970. The innovative response came in the form of mini-mills.

c) Process needs

Around 1909, a statistician at the American Telephone & Telegraph Company projected two curves 15 years ahead; telephone traffic and the American population. Viewed together they showed that by 1920 or so every single female in the United States would have to work as a switchboard operator. The process need was obvious, and within two years, AT&T had developed and installed the automatic switchboard.

d) Industry and market changes

When an industry grows quickly (±40% over ten years), its structure changes. When market or industry structures change, industry leaders neglect the fastest growing market segments because new opportunities rarely fit the way the industry has always approached the market. Innovators therefore have a window of opportunity to establish themselves and become the market leaders.

Three additional sources of opportunity exist outside a company and its social and intellectual environment (Drucker, 1985):

e) Demographic changes

Of the outside sources of innovation opportunity, demographics are the most reliable. Demographic events have a known lead-time, for example the labour force of any country 15 years hence has already been born. Yet, because policy makers often neglect demographics, those who watch them and exploit them can reap rewards. The Japanese are ahead in robotics because they paid attention to demographics.

f) Changes in perception

"The glass is half-full" and "the glass is half-empty" are descriptions of the same phenomenon but which have vastly different meanings. Changing managers' perception of a glass from half-full to half-empty opens up big innovation opportunities.

g) New knowledge

Among history-making innovations, those based on new knowledge - whether scientific, technical, or social - rank high. They are the super stars of entrepreneurship; they get the publicity and the money. They are what people usually mean when they talk of innovation, though not all innovations based on knowledge are important. Some are trivial. Knowledge-based innovations have the longest lead-time of all innovations.

Roberts (1988) distinguishes between "push" and "pull" technology drivers. Managerial research has repeatedly demonstrated that 60 to 80 percent of successful technical innovations seem to have been initiated by activities responsive to "market pull" i.e. forces reflecting orientation to a perceived need or demand.

Despite the presumed dominant role of "market pull" as a source of innovative projects, "technology push" i.e. undertaking projects for advancing the technical state-of-the-art in an area without anticipation of the specific commercial benefits to be derived, is also a critical source of many significant product and process successes. Because innovation is both conceptual and perceptual, it is necessary to have a "must go out and look, ask and listen" attitude. Successful innovators use both the right and left sides of their brains. To be effective, an innovation has to be simple and it has to be focused. It should do only one thing, otherwise it confuses people (Drucker, 1985). Norton and Bass (1992) have empirically established that most individuals lack the capability and inclination to deal with complexity. Although there are great individual differences, most people have very short attention spans.

Most individuals are also very efficient processors of routine tasks. They do not concentrate on repetitive tasks, once they are mastered. Skills for performing repetitive tasks are repressed in the subconscious memory, permitting individuals to pay attention to things other than performance of repetitive tasks. Ironically as a result, what most individuals think about the most is what they will do, but what they do the most is what they think about the least. March (1981) and Janis (1982) point out that as decision complexity increases, solutions become increasingly error prone, means become more important than ends, and rationalisation replaces rationality.

No one can foretell whether a given innovation will end up a big business or a modest achievement. However, even if the results are modest, the successful innovation aims from the beginning to become the standard setter, to determine the direction of a new technology or a new industry, to create the business that remains ahead of the pack. In innovation as in any other endeavour, there is talent, there is ingenuity and there is knowledge. However, when all is said and done, what innovation requires is hard, focused, purposeful work. If diligence, persistence, and commitment are lacking, talent, ingenuity and knowledge are of no avail (Drucker 1985).

3.2.4.1 Technology waves and cycles

Betz (1993) distinguishes between several types of innovation in terms of size and dimension. These are:

- radical innovation;
- Incremental innovation;
- systems innovation; and
- next-generation technology innovation

Considering the importance of next generation technology, good technology management requires an understanding of the long-term nature of technological development and the history of technology cycles in the past.

This view coincides with the "Long Wave Cycle", as described by Twiss (1992). In the 1930's the Russian economist Kondratieff suggested that the world economy followed a long wave cycle of about fifty years duration. Each cycle consisted of four phases – depression, revival, prosperity and recession (Figure 3.1). He was writing at the time of the 1930's depression, which followed those of the 1880's and 1830's.

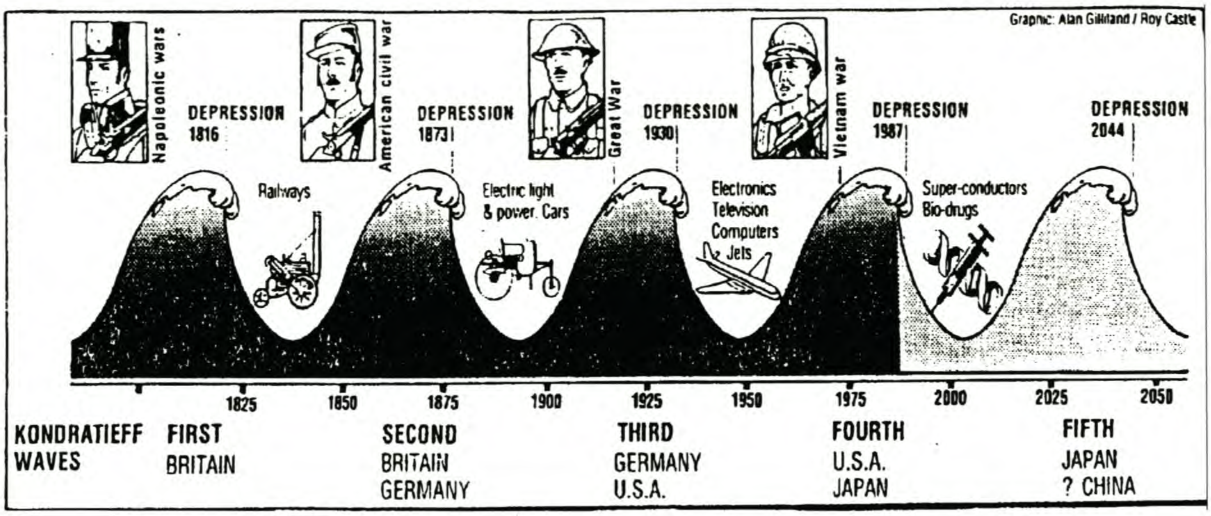


Figure 3.1: A 1987 view of the Kondratieff long waves (Buys, 2000)

His writings were largely neglected in the immediate post-war period when economists and politicians believed they had found solutions to the causes of the economic problems of the 1930's. However, in recent years they have been re-examined as the world economies began to encounter difficulties in the 1980's and early 1990's.

The long wave cycle is linked to advances in technology. When he examined a large number of technological innovations and their dates of occurrence, he found that they too exhibited a similar behaviour, with a burst of industrial innovation occurring at roughly fifty-year intervals. Significantly, these bursts occurred at or around the time of economic depression. Furthermore, the technological innovations of each cycle were based upon the exploitation of different families of technologies and scientific disciplines from those previous cycles.

In order to understand why this occurs it is necessary to elaborate on the distinction made between science and technology in paragraph 3.2.1.

Most scientific advances, the acquisition of knowledge for its own sake, develop in a more or less steady progress punctuated by occasional breakthroughs. Technology, however, which is the application of that knowledge, responds to economic forces.

When the economy is prosperous there is little incentive for companies to invest in risky adventures since growth from existing technology may be adequate to sustain their profitability. This is no longer the case in times of economic recession or depression. Thus, it is under these conditions that new industries are established based upon new technologies developed from existing but previously unexploited scientific knowledge.

One feature of these upsurges of innovation is the important role of new venture entrepreneurial companies. For a number of managerial, attitudinal and organisational reasons, they are often able to succeed in new areas where many of the established industrial leaders fail. These fail to challenge their former strategies in the light of the new circumstances. An understanding of the fundamental changes taking place in the technological environment combined with a formal forecasting system can assist, although they cannot guarantee that an appropriate response will be made.

By reviewing technology history over the past two centuries one can identify the four cycles and associate them with their driving technologies together with their impact on society as follows:

The first industrial revolution. This was founded on the application of power (steam) to industrial processes and transport, most significantly in textiles and the railways. In today's terminology it would be classified as process innovation since there were relatively few consumer products.

The period 1880 to 1920. The next wave was closely associated with the development of the heavy basic industries such as steel and chemicals. It was also a period of heavy investment in infrastructure related to gas and electricity for industrial and domestic use.

The period 1940 to *1970.* This period exhibited rapid growth in the development of new products with a heavy emphasis on the consumer markets.

The period 1980 to present. The current cycle, to which such terms as "Information Society" and "Post Industrial Age" have been attached is based upon innovation stemming from the exploitation of electronics in data retrieval, storage, processing and transmission.

The future. The new millennium shows the beginning of the fifth wave, which should theoretically also last some 50 years. This wave will be carried by innovations, based on microelectronics, robotics and bio-engineering. However, in many respects the current extended economic low seems to be showing characteristics which differ from the lows between previous Kondratieff waves (Bruckman, 1985).

These descriptions of the characteristics of these periods are, of course, generalisations but encapsulate the main thrust of technological development at the time. It should be noted that they are complimentary, and successive cycles have been built upon each other without replacing the industries of the preceding cycles.

Thus while today's growth is coming from the information technologies, there is still a growing consumption of the consumer goods of the previous cycle although with a reduced degree of technological innovation. This leaves relatively little scope for entirely new consumer products, not related to electronics, although the application of new technology may contribute to their improvement. It is therefore changes in emphasis rather than in absolutes. Furthermore, the periods indicated above show when rapid growth occurred rather than when the trend began to emerge. Today, the foundation of the biotechnology industry can be witnessed, but one can only speculate as to whether it will provide the stimulus for the next wave or when it might become a major industrial force. Some observers maintain that the next wave will be powered by materials science and the ability to design materials for a specific application.

Consideration of the long wave cycle does not contribute a great deal to the making of specific forecasts. It might be argued that the fifty-year period is itself somewhat arbitrary and is dependent upon a number of assumptions that are open to question. Nevertheless, its relationship to technology and the sequence of events appear to be soundly based. This helps to gain an understanding of the evolution of technology in industrial societies and to place current and future developments in a historical context. In particular, it is important to note that:

- the technologies, which provide the stimulus for industrial development and the greatest potential for innovation, vary from one cycle to the next;

- a new cycle is associated with new company formation rather than the adoption of the new technology by the market leaders, which sustained their past growth by exploiting the previous generation of technologies;
- during the revival period, new technology is the main motor for corporate growth and profitability. It is preceded by a period when financial discipline, cost cutting and productivity are all important. Thus, the different demands of the stages in the cycle require a reappraisal of corporate values and the priorities attached to technology. Examination of the long wave cycles indicates that we are entering a period of renewed economic growth. If this is accepted, greater emphasis must be placed upon the role of technology in the formation of corporate strategies;
- the social impact, and consequently the demands of the market have been significantly different in the various cycles. Amongst these one can note urbanisation, trade unionism, mass production and consumerism as some of the manifestations of these social responses; and
- industrial leadership has changed from one cycle to the next – firstly Britain, followed by Germany, the USA and today Japan (Twiss, 1992).

Bruckman (1985) believes that waves ranging over a longer time period than Kondratieff waves, may exist. He explains how we may be on the brink of a new socio-economic age rather than between two Kondratieff cycles. Economic history is divided into 3 stages; the pre-industrial age, which lasted until the end of the 18th century; the age of industrialisation, which lasted for two hundred years (late 18th to late 20th century); and the post-industrial age, from the 20th century onwards.

Bright (1963) believes that because of advances in technology innovation, we are only a step away — and not a technological step, but only a price-marketing step — from competition between communications and transportation for the business traveller's dollar. He asks the questions: "Why do businessmen travel? For vocal communication? Discussion of papers? Face-to-face confrontation? Mutual examination of product or service features? Exchange of documents? Signing of papers?". All these things can be done right now by integrated communications systems such as closed circuit TV, computers and the internet. Opportunities in marketing will increase greatly. A company will not be as limited as it once was to certain areas and industries. However, to capitalise on the marketing potential

requires (a) an aggressive, active attitude toward technological change, and (b) a willingness to risk funds and reputation in technological innovation.
The competitive life span of many products will decline rapidly because of technological obsolescence (which is something quite different from physical deterioration or style obsolescence).

Every industry undergoes a life cycle. It is the aggregation of the life cycles from the totality of industrial activity that generates the varying economic conditions represented by the long waves (Twiss, 1992).

It is often possible to associate an industry with one dominant technology. Thus, one can refer to the electronic, electrical or chemical industries whilst recognising that each is also dependent upon contributions from many other technologies. The evolution of an industry is closely associated with that of the dominant technology. Thus, it is possible to think in terms of an industry/technology life cycle. This is a valuable concept which helps us to understand how the contribution of technology varies as an industry matures.

A typical industry/technology life cycle is shown in Figure 3.2. Each stage of this evolution requires a different technological emphasis.

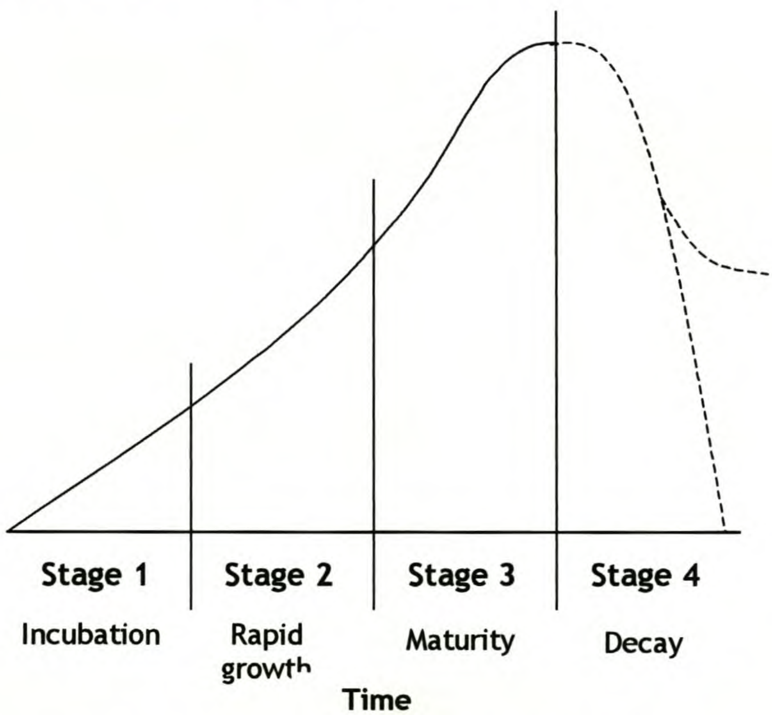


Figure 3.2: The industry/technology life cycle (Twiss, 1992)

The industry life cycle can be analysed as consisting of four broad stages of development.

Stage 1: Incubation. This is the earliest phase in the growth of an industry when the first applications of a new technology emerge. Because of its newness, products incorporating the new technology are likely to be extremely unreliable and there will be no consensus regarding the most appropriate applications or design configurations, nor will the products be attractive to a significant number of prospective purchasers. Thus, the early motor cars exhibited a wide range of technical solutions – petrol or steam engines, air or water cooled, steered by tillers or wheels and chain or shaft transmission. Towards the end of this stage the new technology is likely to find a specialist market where its performance characteristics outweigh the unreliability and high cost; this leads to limited industrial production. During this stage the performance of the technology will be improving rapidly although it is accompanied by slow growth in the output of products using it.
It should also be noted that there are a number of important managerial implications for technology deriving from the different requirements of the life cycle stages. These affect the role and status of technology in the organisation, the type of management systems and the organisational structure. This is an important managerial consideration in a multi-product company employing technologies at different stages in the life cycle and can inhibit the ability of the mature company to innovate effectively.

The differences in the contribution of technology relate to the emphasis placed on development. Thus, the development of manufacturing processes is important in Stage 1 but it is not the critical factor for achieving a competitive advantage. Similarly, it is still possible to introduce product innovations in Stage 3 although process innovations should be emphasised.

The potential of new and current technology as a resource for future growth is an important input to the corporate strategic formulation process. However, the corporate strategy provides the framework within which the technological strategy itself must be formulated. Because these strategies relate to the future, forecasting must be undertaken to ensure that not only does the strategy meet the future market needs but also fully exploits the advances in technology.

There are two important points to note about this period. Firstly, the competitive advantage of the companies (often many in number but small in size) depends solely upon the performance of their products. Product lives are short before others replace them with significantly higher performance. The technology is all-important for commercial success. Secondly, the purchaser, often military or scientific, is more concerned with performance than cost. Thus, the timing of a new product launch is much more important than low development cost, provided, of course, that the developer can acquire the necessary funds to complete the development.

A complex web of relationships between technological, economic, social and political developments determines the business environment and the corporate threats and opportunities arising from it. The large number of issues and their complex set of inter-relationships pose a formidable problem for the forecaster. He must ensure that no significant trends or events and their mutual impacts are ignored whilst reducing them to a number, which can be handled conveniently.

Stage 2: Rapid growth. This is a period of rapid growth for an industry. By the beginning of this stage the main features of the product design are likely to have emerged. In the case of the motorcar, these main features, which had been retained almost universally for the past eight decades, were a water-cooled internal combustion engine, four wheels, shaft transmission and a circular steering wheel. Technology is applied to the improvement of a product, which satisfies the performance, reliability and cost criteria of a substantial and rapidly growing market. Technical improvements will continue but will be less radical. In the motorcar for example, monocoque construction replaced the rigid chassis and four-wheel brakes replaced disc brakes and drum brakes. Many of the early producers will have disappeared, although there will still be a substantial number of manufacturers of distinctive products.

At this stage, the market begins to segment and product designs are focused upon the needs of particular groups of buyers. Thus the technological improvements are aimed to differentiate the product in relation to the different demands of these market segments. The corporate emphasis changes from technology push to market pull.

Stage 3: Maturity. Rapid market growth cannot be maintained indefinitely and a time will approach when an industry reaches maturity and the market becomes saturated. By this time, most of the market segments will have become well defined and, because of the maturity of the technology, the products become more difficult to differentiate with similar offerings from all the manufacturers. Price is now a major consideration for the purchaser and company profitability is closely associated with the ability to manufacture at low cost. A few dominant manufacturers emerge offering products of very similar design. Since competitive advantage is derived from manufacturing efficiency, the main contribution of technology is to produce at lower cost through process innovation.

This does not mean that there is no place for product innovation, but its main contribution is to add value, usually for the smaller niche markets. Thus, one sees the development, for example, of four wheel drive, four wheel steering and ABS braking systems in motorcars. Initially, however, these markets are relatively small although the value added and profitability are higher than for the mass-market models.

Stage 4: Decay. Eventually an industry reaches a peak. The future can then take two forms. The most serious is when an entirely new solution to the market needs, usually associated with a new technology, emerges. The market may disappear, as with the slide rule and the gas mantle, or be satisfied by a significantly different production solution, an electronic rather than a mechanical watch. Faced with this situation a company either diversifies or goes out of business. One form of diversification is technological, by applying the existing technology in new products or adopting the new technology to satisfy current markets. The latter would appear the more desirable, although history indicates that the new technologies are usually exploited by those companies applying technological expertise to markets new to them, rather than by those who attempt to adopt the new technologies where they possess a market strength.

However, there may be a long-term market for the product. Competitive pressures often force companies to seek a larger market share. One way this is frequently done is to apply technology to increase the in-use life of the product, but in a saturated market, which is largely a replacement market, any increase in product longevity merely leads to a diminution of the total market size. In the motor industry this can be observed in both the tyre and battery industries and is beginning to affect the motorcar itself, as corrosion resistance improves.

There are other ways in which technology can be applied to obtain competitive advantage, but which reduce the total output of the industry whilst satisfying the same number of customers. The replacement of mechanical components by cheaper electronic ones or the development of lighter metal cars, that reduces the cost of the product, and ultimately its price, have this effect. More effective drug delivery systems enable patients to be cured with a smaller quantity of the drug. In all these examples, the search for competitive advantage is likely to lead to a smaller output volume for the industry as a whole. Each company may see the wisdom of this course of action, however not to, would be to guarantee failure, but inevitably there must be losers (Twiss, 1992).

Betz (1993) comments on a study by Achilladelis and Associates, which identified the innovations introduced by the chemical industry from 1930 to 1980 in the two product areas of pesticides and organic chemical intermediates. They identified 634 pesticide innovations and 821 organic intermediate innovations. Next, they asked specialists to rank the innovations in terms of two criteria: originality and market success. They found that the more original (the more radical) the innovation, the more likely it was to be a commercial success. Radical product innovations provide more differentiation in competition than incremental innovations and therefore are more likely to be commercially successful. The impact of radical innovation is to stimulate a new market, whereas incremental innovations enable continued dominance in an existing market. At the end of a period of radical innovations in an industry, markets mature, excess production capacity occurs, and fierce competition for maintaining market shares together reduce profitability for all participants in the industry.

3.2.4.2 Technological discontinuities and S-curves

At rare and irregular intervals in every industry, innovations appear that command a decisive cost or quality advantage and that do not strike at the profit margins and the outputs of the existing firms, but at their foundations and their very lives (Schumpeter, 1942). Such innovations depart dramatically from the norm of continuous incremental innovation that characterizes product classes, and are termed technological discontinuities. These discontinuities either affect underlying processes or the products themselves. Figure 3.3 illustrates how one discontinuity follows on from another.

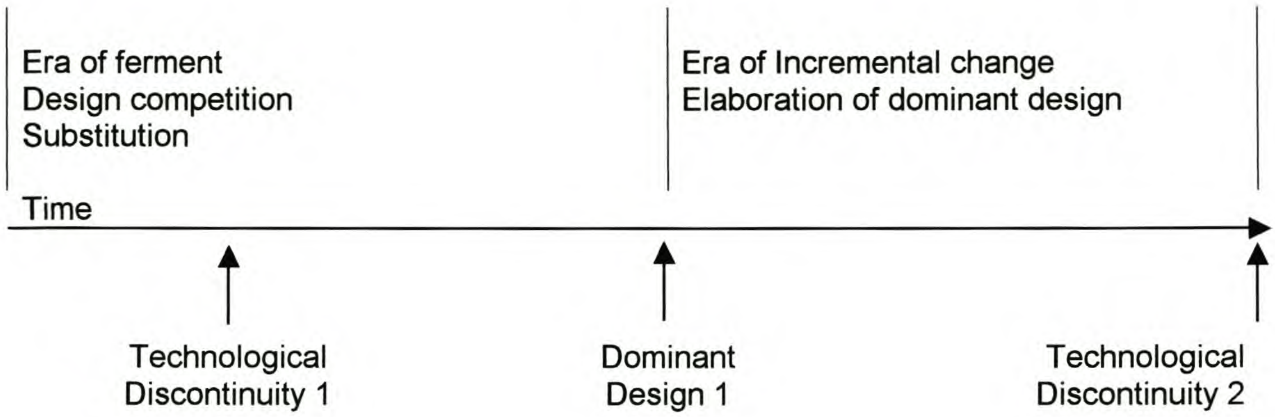


Figure 3.3: The technology cycle (Anderson and Tushman, 1990)

A competence-enhancing discontinuity builds on know-how embodied in the technology that it replaces. For example, the turbofan advance in jet engines built on prior jet competence, and the series of breakthrough advancements in mechanical watch components built on prior mechanical competence. The introduction of a radical advance increases variation in a product class. A revolutionary innovation is crude and experimental when introduced, but it ushers in an era of experimentation as organisations struggle to absorb (or destroy) the innovative technology. Two distinct selection processes characterise this era of ferment; competition between technical regimes, and competition within the new technical regime. This period of substantial product-class variation and, in turn, uncertainty, ends with the emergence of a dominant design (Anderson and Tushman, 1990).

Older technological orders seldom vanish quietly and often lead to fierce competition between old and new technologies (Foster, 1986). New technologies are disparaged when they are introduced because they frequently do not work well and are based on unproven assumptions and on competence that is inconsistent with the established technological order (Schön, 1971; Jenkins, 1975). The response of the existing community of practitioners is often to increase the innovativeness and efficiency of the existing technology. Substitution does not immediately follow the appearance of a radical innovation but the eventual supplanting of a new technology is rapid once the superiority of the new technology is established. When a breakthrough innovation builds on existing know-how, the era of ferment is relatively short. Once a design becomes an industry standard, it is difficult to dislodge. Volume production of the dominant design creates economies due to learning by doing. Dominant designs emerge from each breakthrough innovation as manufacturers, suppliers, customers, and regulatory agencies compete to decrease the uncertainty associated with variation during the era of ferment. There are several alternative selection possibilities. Market dominance might pass back and forth between rival designs over time; one might achieve temporary ascendance only to be supplanted by a competing design, which it might again overtake. Second, several rival designs might achieve stable and roughly equal market shares. When the competition process is artificially forestalled, dominant designs may well not emerge. Such cases arise under regimes of high appropriability where a firm is able to build a thicket of patents around a technology and control its diffusion via strategic licensing decisions. The emergence of a dominant design is directly linked to the diffusion of a new generation of technology. The majority of potential adopters will await the emergence of an industry standard before purchasing a new product or installing a new process technology. Producers and customers accept a package of relatively well-known innovations and forego the best technical performance in order to reduce technological uncertainty. A number of case studies have suggested that the cumulative effect of numerous incremental advances accounts for the majority of technical progress in an industry. Most of the progress attributable to major innovations actually stems from the series of minor improvements that follow them (Anderson and Tushman, 1990).

Buys (2000) compares technological change with the evolutionary process prevalent in nature (Figure 3.4). Key mutations in nature can be paralleled with new inventions in technology. These inventions will then transform into innovations filling appropriate market niches, as natural mutations adapt to fill ecological niches (the beaks of certain hummingbird species have adapted in such a way over time that they only have the ability to extract nectar from one specific species of flower). Plants and birds have become totally interdependent on each other for survival. If an innovation does not adapt to the changes facing it in the business environment, then it becomes obsolete (extinct in the natural world).

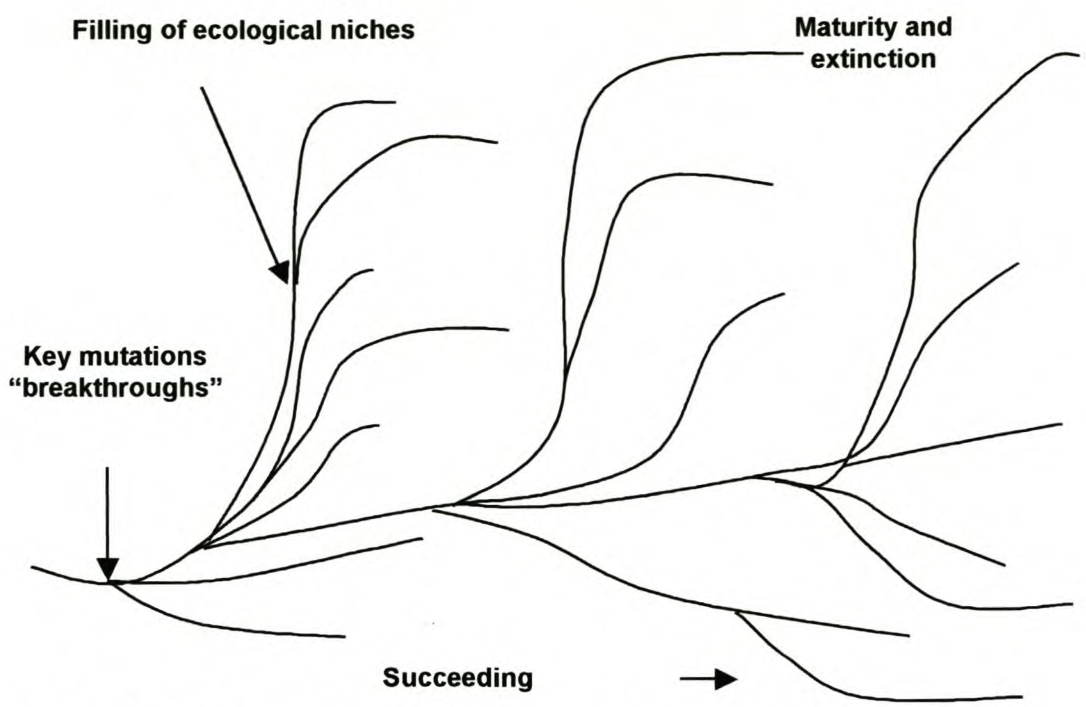


Figure 3.4: Similarity between technological change and natural evolution (Buys 2000)

The technical progress in a technology S-curve describes a history of incremental progress in a technology. Large leaps in technical progress "jumps" technology from one S-curve to a new, higher one. Such leaps in progress occur as a result of the invention of different phenomenal bases for the technology which require different practices in product design or production. These are called discontinuities in technical practice.

A next-generation technology results from such a major leap in the performance of an existing technology system. It may occur as a result of an accumulation of incremental innovations of different parts of the system, a major improvement in a critical component of the system, or changes in the boundaries or architecture of the system (Betz, 1993).

Large discontinuous leaps in technology have different economic impacts than those of smooth, incremental changes or progress in technology. When technological change is continuous, research planning can fit within the firm and its R&D organisation. When technological change is discontinuous, the firm must depend on and be responsive to research outside the firm and innovation that does not fit into the current organisation of the firm. Technology discontinuities create innovative situations in which one must literally "bet the company" (Betz, 1993). Incremental technological progress reinforces an industrial structure, while discontinuous technological progress alters industrial structures.

In conclusion, it is clear that there are various cycles for various periods over the economic history of man. Each cycle is subdivided into smaller cycles. These cycles are, from longest to shortest, industrial cycles, Kondratieff cycles, industry cycles, technology cycles and product cycles. Figure 3.5 illustrates how these cycles follow upon each other.

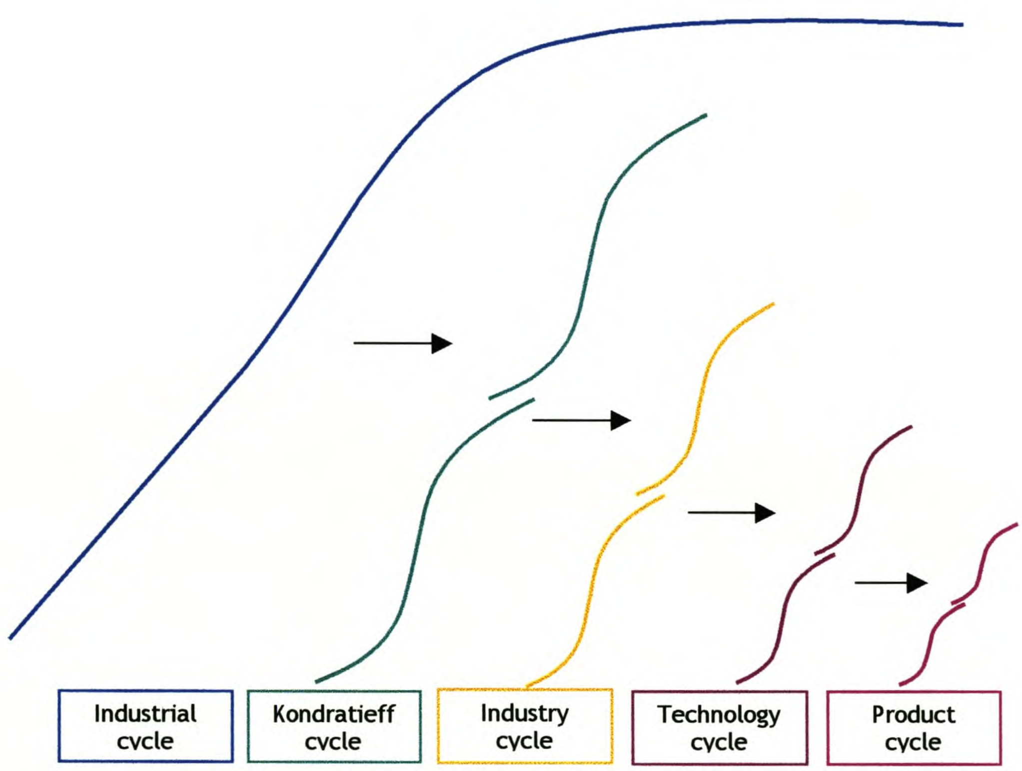


Figure 3.5: Chronology of various economic cycles

3.2.4.3 Competitiveness in a global market

Figure 3.6 illustrates a simple macro-economic growth model, as described by Buys (2000). Any national economy has inflows, requiring resources (labour, capital and technology) and outflows in the form of capital, goods and services.

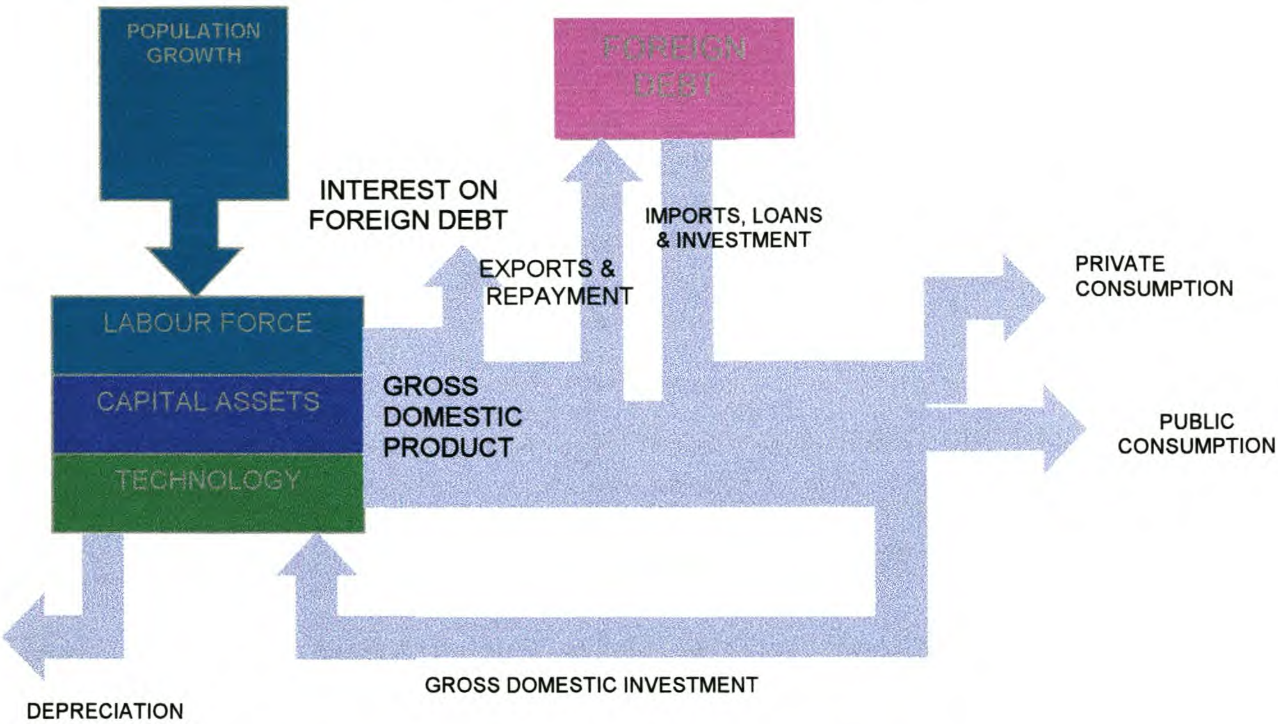


Figure 3.6: A simple macro-economic growth model (Buys, 2000)

Through productivity gains, superior design, technological competition and the economics of large-scale organisations (including the economics of distribution), the costs of many materials, products, and services may decline (Bright, 1963). Sunter (1997) refers to this as the falling price boom.

Buys (2000) contends that technology is not a sufficient condition for economic growth if it cannot be leveraged to achieve international competitiveness.

International competitiveness is the ability of a nation to produce goods and services that meet the test of international competition while providing sustained increases in the standard of living of its citizens. A major reason for many countries remaining uncompetitive is due to what is referred to as the "competitiveness trap". Buys (2000) describes these traps as situations where the current *status quo* contributes to the retention of the *status quo*, making it difficult, if not impossible to escape. He describes two examples of such traps:

- Low income leads to insufficient education and training, which leads to low future income.
- Low competitiveness leads to low income, which leads to insufficient R&D, which leads to low future competitiveness.

The principal goal of a nation is to produce a high standard of living for all of its citizens. Productivity is the prime determinant in the long run of a nation's standard of living, as it is the root cause of national per capita income. A rising standard of living depends on the capacity of the nation's firms to achieve high levels of productivity and to increase productivity over time. To achieve this an economy is required to continually upgrade itself.

Firms must continually improve productivity in existing industries by raising product quality and adding desirable features to their products by harnessing appropriate technology. Germany, for example, has enjoyed rising productivity for many years by doing the above. A nation's firms must also develop the capabilities required to compete in more and more sophisticated industry segments, where productivity is generally higher. At the same time, an upgrading economy is one, which has the capability of competing successfully in entirely new and sophisticated industries. Doing so absorbs human resources freed up in the process of improving productivity in existing fields. Porter (1990) explains that the above theory is the reason why cheap labour and a "favourable" exchange rate are not meaningful definitions of competitiveness (see Figure 3.7). The aim is to support high wages and command premium prices in international markets. A nation can specialise in those industries or segments in which it is relatively more productive and import those products and services where its firms are less productive, thereby raising the productivity level of the economy as a whole. Leading international competitors are not only frequently located in the same nation but are often found in the same city or region within the nation.

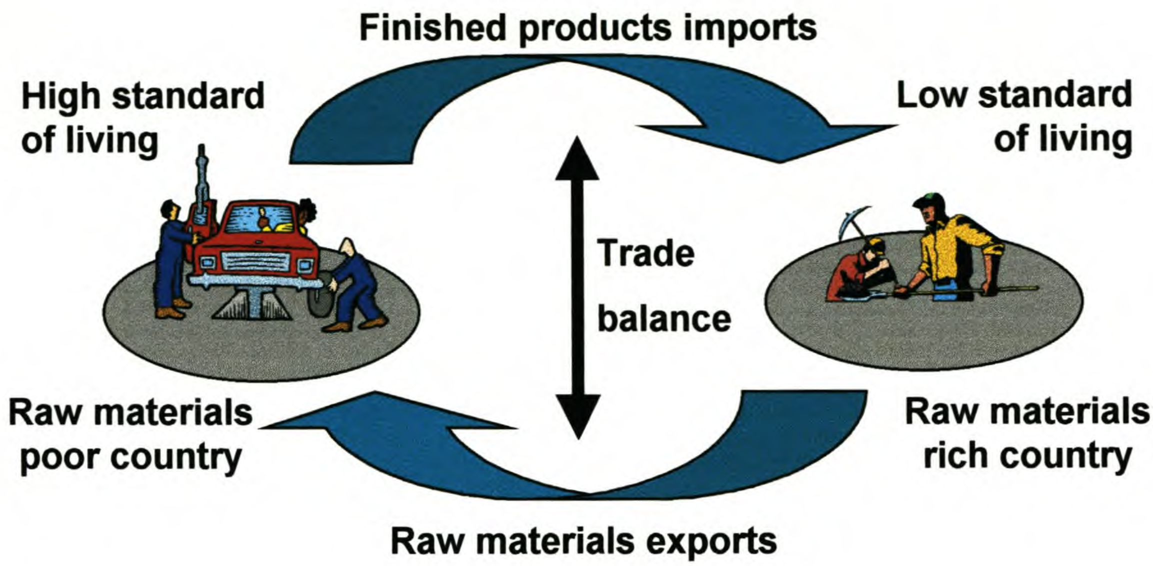


Figure 3.7: The curse of raw materials (Buys, 2000)

In many industries, and especially in distinct segments of industries, competitors with true international competitive advantage are based in only a few nations. The influence of the nation applies to industries and segments rather than to firms *per se*.

Buys (2000) divides the world into 2 types of technology colonies. Technology colonies of the first kind have been more successful in terms of competitiveness and economic performance. Technology colonies of the second kind have been relatively less successful. Table 3.1 summarises the core industry characteristics in countries representing each of the above two types of colonies. A common ingredient of the technology colonies of the second kind is the reliance on raw materials. In the twenty-first century man-made comparative advantage, with the emphasis on process technologies, will be the starting point for economic competition. Natural resources essentially drop out of the equation. Traditional raw-material suppliers in the Third World will find even smaller markets for their cheaper resources.

Table 3.1: Examples of technology colonies of the 1st and 2nd kind (Buys, 2000)

Technology colonies of the 1st kind	**Technology colonies of the 2nd kind**
Human resource providers	**Commodity providers**
Singapore (electronics)	Middle East (oil)
India (programmers)	Africa and South America (minerals and agricultural products)
Taiwan (computers)	Russia (minerals)
Korea (motorcars)	
China (manufacturing)	

Even for colonies of the first kind, there is the disturbing probability that sound traditional management, a good market, sound financing, and good competitive equipment and costs will not necessarily provide job security. No automation equipment in history ever knocked out jobs as fast as the shift from bombers to missiles. New jobs were created, but they were not the same jobs, nor were they in the same locations. There will be more risk (and more failure) for business decisions in this kind of a world. The common system of basing a manager's rewards only on last year's profits does not encourage anyone to pursue a project that might only pay off in five years time. Both the traditional reward system and the traditional organisation need revision to encourage the sound appraisal of, and response to, technological opportunities (Bright, 1963).

Due to the competitiveness trap, enhanced by the curse of raw materials, technology colonies of the second kind are primarily consumers of technology, as opposed to technology colonies of the first kind, which are primarily producers of technology. This is confirmed by Porter (1990), who states that the creation of basic factors (such as natural resources, climate, location, unskilled labour and debt capital) requires modest private and social investment. Increasingly, such factors are either unimportant to national competitive advantage or the advantage they provide for a nation's firms is unsustainable. Advanced factors are now the most significant ones for competitive advantage. They are necessary to achieve higher order competitive advantages such as differentiated products and proprietary production technology.

3.2.4.4 Competitive strategy

Essentially, the development of a competitive strategy is developing a broad formula on how a business or industry is going to compete, what its goals should be, and what policies will be needed to carry out those goals. Porter (1980) refers to the "wheel of competitive strategy", as depicted in Figure 3.8.

Figure 3.8: The wheel of competitive strategy (Porter, 1980)

In the hub of the wheel are the firm's goals, which are its broad definition on how the firm wants to compete. The spokes of the wheel are the key operating policies, which allow the firm to achieve its goals. Like a wheel, the spokes (policies) must radiate from and reflect the hub (goals), and the spokes must be connected with each other or the wheel will not turn.

Porter (1980) also refers to four key factors which need to be considered in order to formulate a competitive strategy. These factors define the limits of what a firm can successfully accomplish. These factors, as shown in Figure 3.9 indicate that two factors are internal to the company and two external.

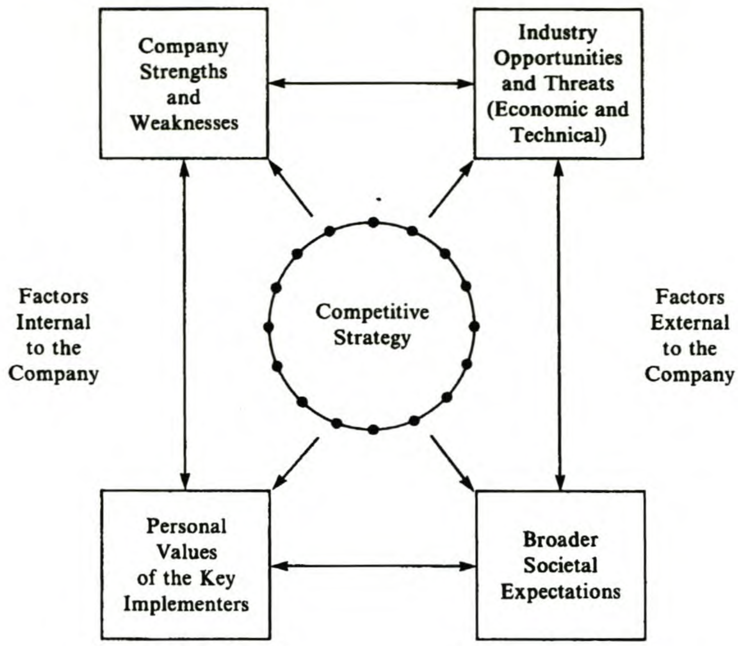


Figure 3.9: Competitive strategy (Porter, 1980)

It has, however, become more common in recent years to analyse the internal and external environment through a set of factors which are responsible for the driving of change. These factors are:

- political;
- economical;
- social;
- technological; and
- environmental

The techniques used to scan the internal and external environments are discussed in detail in Chapter 4. The remainder of this Chapter discusses the importance of incorporating technology in any strategic analysis.

3.2.4.5 Technology and strategic planning

Radical and incremental innovations occur at different rates, with radical innovation being relatively unpredictable. Thus, in an established industry, organising research primarily for incremental innovation, radical innovation is always a surprise. This leads to a problem, for management aims at reducing the uncertainty in operations to predictability, and therefore, surprise is always unsettling to management planning. Next-generation product planning in a large firm is a complex issue because of the differing technical and market views held by different divisions and research laboratories of the firm. To formulate a technology plan for a technology discontinuity, it is necessary for a high-level executive to force the issue and to organise the effort necessary to formulate and implement a technology strategy for the whole company. Technology discontinuities are a major source of organisational instability. At least part of the reason for substantial organisational decline in the face of environmental change lies with the executive team. A set of executives who have been historically successful may become complacent with existing systems and/or be less vigilant to environmental changes. On the other hand, even if an executive team registers external threat, they may not have the energy and/or competence to effectively deal with fundamentally different competitive conditions. The importance of an effective executive team is accentuated in industries where the rate of change in underlying technologies is substantial.

The conduct of a firm consists of the strategic, tactical, and organisational activities guided by the executive team (chief executive officer (CEO) and other principal executive officers). Conduct must alter as the context of the firm changes when alterations in the economic structure affect competition. Changes can arise from technological changes, market changes, resource changes, regulation changes, and competitive changes. Performance then depends on the executive team anticipating a correct strategy and organisation for the future structure of the economic system. Such a strategy and organisation must correctly anticipate technological opportunities for new products, market changes for new needs and applications, resource changes that affect the availability and cost of materials and energy, and changes in government regulations affecting safety, monopolies and taxes.

Over the periods in which industries faced changes in economic structural factors, those firms whose executive teams made no changes in strategy and organisation had products that failed after the structural changes occurred. However, those firms whose executives constantly made changes in strategy, organisation and product also failed.

The firms that survive and prosper through a technology discontinuity are those whose executive teams firstly correctly anticipate the discontinuity and prepare for it with appropriate technology strategy, product planning, and reorganisation and secondly, after making the appropriate changes, hold a steady course to produce with quality and lowered costs (Betz, 1993).

With hindsight, it is easy to pick out why and even when a new technology substituted for an old technology or even how, over time, incremental improvements in part of a technology system resulted in a wholly new technology system – technology discontinuities. Yet the problem in forecasting and planning technology is to anticipate the change. Technological innovation can affect a firm by either preserving or destroying competencies in production and/or in marketing. Abernathy and Clark (1985) classified technological innovations according to whether they preserved or destroyed such corporate competencies:

- Regular innovations preserve production competencies and market competencies.
- Niche-creation innovations preserve production competencies but disrupt market competencies.
- Revolutionary innovations obsolete production competencies but preserve market competencies.
- Architectural innovations obsolete production competencies and disrupt market competencies.

Current corporate strategies can successfully deal with regular and niche-creation innovations because the technical skills base of the organisation is not affected. However, the revolutionary and architectural innovations require true strategic re-orientations, for example the re-orientation of production and market competencies (Betz, 1993).

Pavitt (1990) distinguishes between the key characteristics of innovative activities in the firm:

Activities are cumulative. Most technological knowledge is specific, involving the development and testing of prototypes and pilot plants. Although firms can buy-in technology and skills from the outside, what they have been able to do in the past strongly conditions what they can hope to do in the future.

Activities are highly differentiated. Specific technological skills in one field (e.g. developing pharmaceutical products) may be applicable in closely related fields (e.g. developing pesticides), but they are not much use in many others (e.g. designing and building motorcars).

Continuous and intensive collaboration and interaction among functional and professional specialised groups are required, and R&D, production, and marketing are to be given the tools to successfully implement and finance moves into new areas.

The two characteristics noted above have major implications for theory and action related to the content of technology strategy, to the processes through which they are developed and implemented and to institutional continuity in the face of technological discontinuity.

The areas of technology management affected by technology analysis are primarily those of normative and strategic management. On the strategic level technology analysis provides a deepened basis for the elaboration of strategic decisions. In addition, it is valid for value permeation of company culture and together with technology forecasting, influences the shaping of company and technology policies. (Tschirky, 1994).

The industry life cycle described in Chapter 2.4.1 can assist management in their formulation of strategy. It forces them to look ahead to the evolution of a dynamic situation rather than to respond to short-term signals.

The technology strategy is analogous to the business strategy. It is concerned with the allocation of resources between alternatives. It therefore involves choice. The main technological alternatives are:

- the acquisition of new technologies;
- the development of radical new products;
- incremental product improvement;
- the development of new production processes; and
- the improvement of existing production processes.

Because of financial constraints, it is essential to formulate a technology strategy which ensures that the available resources are allocated in a way that makes the greatest corporate contribution. Since the needs of the corporate strategy change with time, so must the technology strategy. It is the timely introduction of these changes and their associated managerial implications which determine the effectiveness of the technological contribution. The consequence of intensively pursuing a cost minimisation strategy is a reduced ability to make innovation changes and to respond to those introduced by competitors – although the amount of loss seems to depend on the degree to which the manufacturer follows such a strategy, and its intensity (Abernathy *et al.,* 1974).

In developing forecasts for the whole business environment it has been stressed that technological considerations must be taken into account at each stage of the process.

Disillusionment may follow early disappointments and many companies withdraw from the market only to miss the opportunity when demand begins to grow rapidly. The final danger occurs as the market approaches saturation. Looking backwards at past growth, rather than forecasting the approach of saturation, can lead to heavy investment for a level of demand which will never eventuate. The resultant over-capacity is a characteristic of many companies in industries at this stage of development.

Van Wyk (1988) questions the past role of the Board in strategic management and describes a typical Board meeting where the members of the corporate Board would fly in the night before; dine with their old friend, the chief executive, sharing after-dinner brandy and camaraderie. Each director would receive a slender binder of briefing papers that, typically, got a cursory read before the formality of the next morning's Board meeting. The chief executive called the tune, the Board hummed along. He differentiates between 3 modes of operation:

The watchdog. The role of the Board is that of monitor. "This implies a post-factum assessment, primarily in terms of how successfully the organisation conducts its business."

The trustee. The Board serves as the guardian of the assets. "Implicit in this role is the sense that the trustee is responsible for evaluating what the corporation defines as its business, as well as how well that business is conducted."

The pilot. The Board takes an active role in directing the business of the corporation. "A pilot Board is active, gathers a great deal of information, and takes on the decision roles the other archetypes leave solely to management."

A good starting point for top management to understand Technology Strategy is to affirm that the core of a company is what it knows and what it can do, rather than the products that it has or the markets it serves. Technology Strategy is that aspect of strategy which is concerned with exploiting, developing and maintaining the sum total of the company's knowledge and abilities. Technology Strategy demands a long-term perspective, as shown in Figure 3.10. Each sub-cycle represents a generation in an overall technology. For example, in computer software, separate generations are distinguishable within the overall type of software for a major application. A company needs to make sure that its technology acquisition investment has not stopped with the first generation and hence left it ill equipped to cope with competitors with second-generation technology.

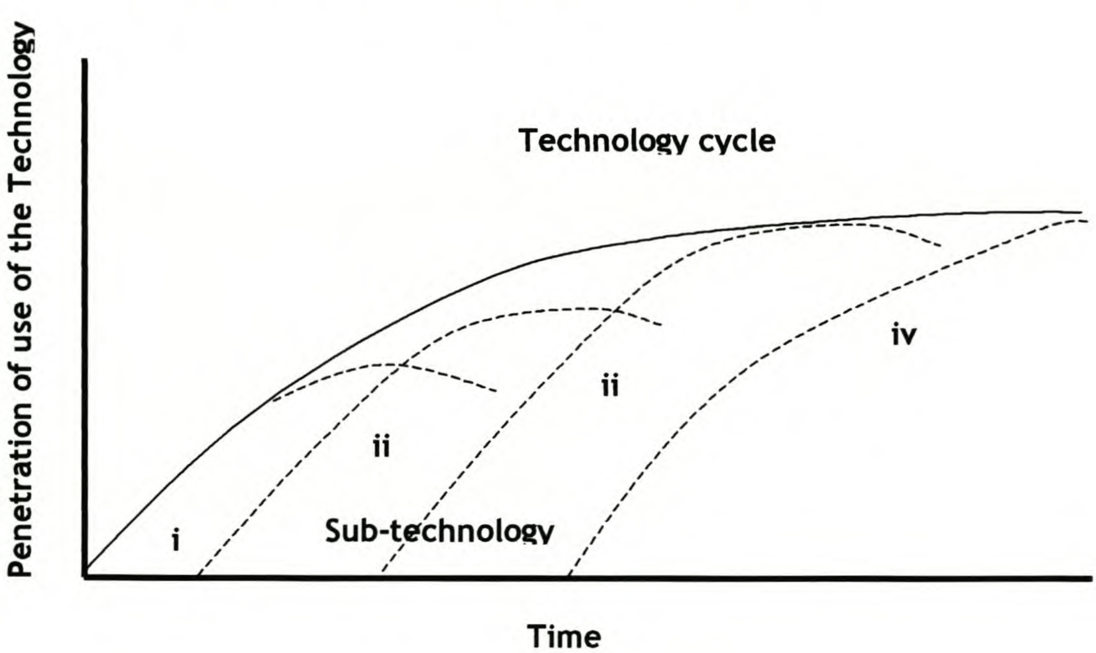


Figure 3.10: Technology cycles (Ford, 1988)

Ford (1988) summarises the reasons why companies find it difficult to implement a technology strategy as follows:

An important initial problem is what has been described as the "Technological Illiteracy" of many chief executives and managers. A second problem might be referred to as the "high-tech syndrome" and this has a number of aspects. Firstly, it leads managers to believe that technology is synonymous with high technology and hence that a coherent view of the technological base of a company is only necessary for high-tech companies. Of course, high technology industries are characterised by faster rates of change. However, this does not mean that companies in slower changing areas should not constantly assess the success of their acquisition and exploitation. In fact it is in these apparently lower technology areas where complacency can lead to erosion of an unrecognised technology base and where sub-optimal technology exploitation may be tolerated.

Another problem in introducing a technology strategy is that it requires quite different and enhanced patterns of communication in the company.

Questions that need to be investigated, with regard to the role of technology in a firm, have been summarised by Ford (1988):

- What are the technologies and know-how on which our business depends?
- Do we have a poor record in bringing "home grown" technologies to market?
- How does our technology position compare to that of our customers?
- What is the life cycle position of the technologies on which we depend?
- What are the emerging or developing technologies both inside and outside our company, which could affect our current prospective market?
- Are the company's strengths in product or production technologies or both?
- Does the company achieve the optimum exploitation of the technologies we have?
- Does the company have technological assets, which are no longer of use to us, but which may be of value to other companies?

In sectors like electronics, aircraft, and fine chemicals, companies' expenditures on R & D are greater than their investments in fixed equipment and plant (Pavitt, 1990). The changing dynamics of technology management are best seen as an evolving paradigm, driven by the search for a competitive advantage. Technology, as a competitive weapon, was once little more than a "black box" arrangement - people, money, and other resources went in and technological innovations came out, often in unpredictable ways.

As the demand for resources grew and the importance of technology increased during the post-World War II period, the "control" paradigm evolved out of the "black box" framework. This focus led to greater management involvement and controls, most often in the form of project budgets, timetables, and estimated returns on the corporate R&D investment. Within the last decade, a "strategic" approach has evolved out of the "control" paradigm. Referred to as the "Third Generation", this framework argues for an integration of technology with corporate or strategic business unit (SBU) strategy. For many strategists the result has been an attempt to elevate technology management to a level of strategic concern even in industries not considered "technology-driven." The "third generation" paradigm demands that technology management adopts a strategy driven view of the firm's core technology and the potential product streams that can emerge.

The "fourth generation" of technology management is characterised by a seamless stewardship that stretches from the idea stage through to the delivery of higher value added outcomes for customers. Specifically, a sustainable competitive advantage comes from technologies that are proprietary, customers that are "locked in," and competitors that are "locked out" through high barriers to entry and social structures that support effective strategic execution. Technology acquisition goes beyond merely matching desired outcomes with needed technologies. It extends the demands on technology management to include the development of effective social structures that embrace new technologies (Werther *et al.,* 1994).

Successful technology acquisition is one key to a sustainable competitive advantage. Effectiveness in technology acquisition is often more severely impaired by the inability to align the goals of departments, functions, and hierarchical levels vertically and horizontally around the new technology. This inability often stems from resistance generated by the organisation's social structure.
Technologies that are incremental refinements and have been developed internally are likely to receive the lowest levels of resistance, but evolutionary refinements,

such as moving from hydraulic brakes to power-assisted hydraulic ones in motorcars, are seldom a source of sustainable competitive advantage.

Figure 3.11 suggests that when technologies are both external and radical, the resistance to their implementation may be very high, presumably because of the greater disruption to the organisation's social system.

		Types of Technology	
		Incremental	Radical
Sources	Internal	Low	High
	External	High	Very high

Figure 3.11: Relative organisational resistance to technology acquisition based on types and sources of technology (Werther et al., 1994)

Attempts to build consensus about the acquisition of technologies must deal with both the degrees of resistance and the need for executive-level information. Vertical (up and down the organisation) information flows are needed to ensure that executives who are not technically oriented make informed decisions about the technological needs demanded by production and marketing personnel. Horizontally, consensus about needed technologies must span intra-organisational boundaries.

One approach to addressing this correlation of resistance and executive-level information is the use of a chief technology officer as an internal technology champion. These champions continuously educate all levels of the organisation about technology's strategic contribution. By interfacing with other executives, R&D laboratories, project teams and technology managers, they facilitate an internal flow of information throughout the organisation and serve senior management as internal technology consultants. By championing key technologies through their access to senior management and others, they help break down inter-functional barriers and accelerate the assimilation of internally and externally developed technologies. Internal resistance and informational barriers are most commonly found at departmental boundaries. Functionally organised departments focus on their specific function, often developing a self-centred outlook. Breaking down such myopia often demands a reorganisation around a new focus.

Chief technology officers, multifunctional project teams (MFPT's) and the structural changes they suggest are important first steps to facilitating the assimilation of technologies. Ultimately, however, technology-driven organisations must move beyond these symptomatic solutions. The key to assimilation lies with adjusting the organisation's social system. Success will demand the creation of a "continuously learning organisation" that rethinks the sociological impact of technology management. Then, as the MFPT's are recognised as key leverage points in the organisation's technology acquisition efforts, the use of this internal social structure will be strengthened. Team building, organisational development, and training resources will be directed at MFPT's to improve their ability to identify, evaluate, acquire, and ultimately assimilate technologies that fit the organisation's strategic intent (Werther *et al.,* 1994).

Strategically, the ultimate use of technology is to provide customers with a higher added value than they can get elsewhere. Those who think giving the customer added value is the only use of technology, however, overlook the range of possibilities suggested by Figure 3.12. The strategic deployment of technology addresses customers and competitors through both offensive and defensive approaches. The strategies are labelled "value added", "locking-in", "pre-empting", and "blocking".

		Uses of Technology	
		Offensive	Defensive
Applications	Customers	Value Added	Lock-in
	Competitor	Pre-empt	Block

Figure 3.12: Value chain grid of firms and three operating networks (Werther, et al., *1994)*

Value-added strategies achieve competitive advantage by using technology to provide high value to customers. The goal here is to better enable producers to anticipate the downstream needs of users. Moreover, those producers who can integrate themselves downstream into the planning of their customers will not only acquire better information, they will also gain the ability to evaluate their deployment of technology through the eyes of the users, developing considerable insights into future technologies that need to be deployed.

Pre-emptive strategies use new technology offensively to transform and raise the industry's technical standards. They typically establish or change the technological standards of the industry. These efforts are often associated with first-to-market strategies, and are therefore considered risky. Sony, for example, introduced its Beta format video recorders for the home market in the hope of pre-empting competitors by establishing a new technological standard for video recording. However, by giving consumers longer tapes at a lower cost, VHS video recorder technology became the eventual consumer standard (Werther *et al.,* 1994).

Blocking strategies aim at making entry by competitors into technological areas impossible, or at least unattractive. Unlike pre-emptive approaches, however, successful blocking strategies often rely on defending leadership through an interconnected (and often evolving) cluster of technologies, as opposed to a specific pre-emptive breakthrough.

Locking-in strategies are aimed at the customer by offering an interrelated family of products or products and services, which are sometimes connected through proprietary technologies.

A sustainable competitive advantage comes from technologies that are proprietary, customers that are "locked in", and competitors that are "locked out" through high barriers to entry and social structures that support effective strategic execution. The fourth-generation framework will recast the search for competitive advantage in terms of the organisation's ability to acquire and deploy a variety of technologies. World-class competitors, which by definition, have already fused technology into their corporate strategy, will push the state-of-the-art technology management beyond integration to execution (Werther *et al.,* 1994).

3.2.4.6 Technology innovation in organisations

The linear innovation process for radical innovation involves a series of steps:

- Discovery and understanding.
- Scientific feasibility.
- Invention.
- Technical feasibility prototype.
- Functional application prototype.

- Engineering prototype.
- Manufacturing prototype.
- Product production (Roberts, 1988).

The cyclic innovation process for incremental innovation in the product-development process involves a cyclic set of activities: Betz (1993) summarises these steps as:

- Anticipating technical change.
- Creating technical change.
- Implementing technical change in product/process/service development.
- Introducing high-technology products into the market place.

Figure 3.13 presents six stages, but the precise number and their division are somewhat arbitrary. The key is that each phase of activity is dominated by the search for answers to different managerial questions.

Innovation occurs through technical efforts carried out primarily within an internal organisational context, but involving heavy interaction with the external technological as well as market environment. A proactive search for technical and market inputs, as well as receptivity to information sourced from external sources, are critical aspects of technology-based innovation. All studies of effective innovations have shown significant contributions by external technology and have found success heavily dependent upon awareness of customer needs and competitor activity. One of the most important trends in industrial innovation activity during the 1980's was the continuing increase in the use of external sources of technology as critical supplements to internal R&D efforts (Roberts, 1988).

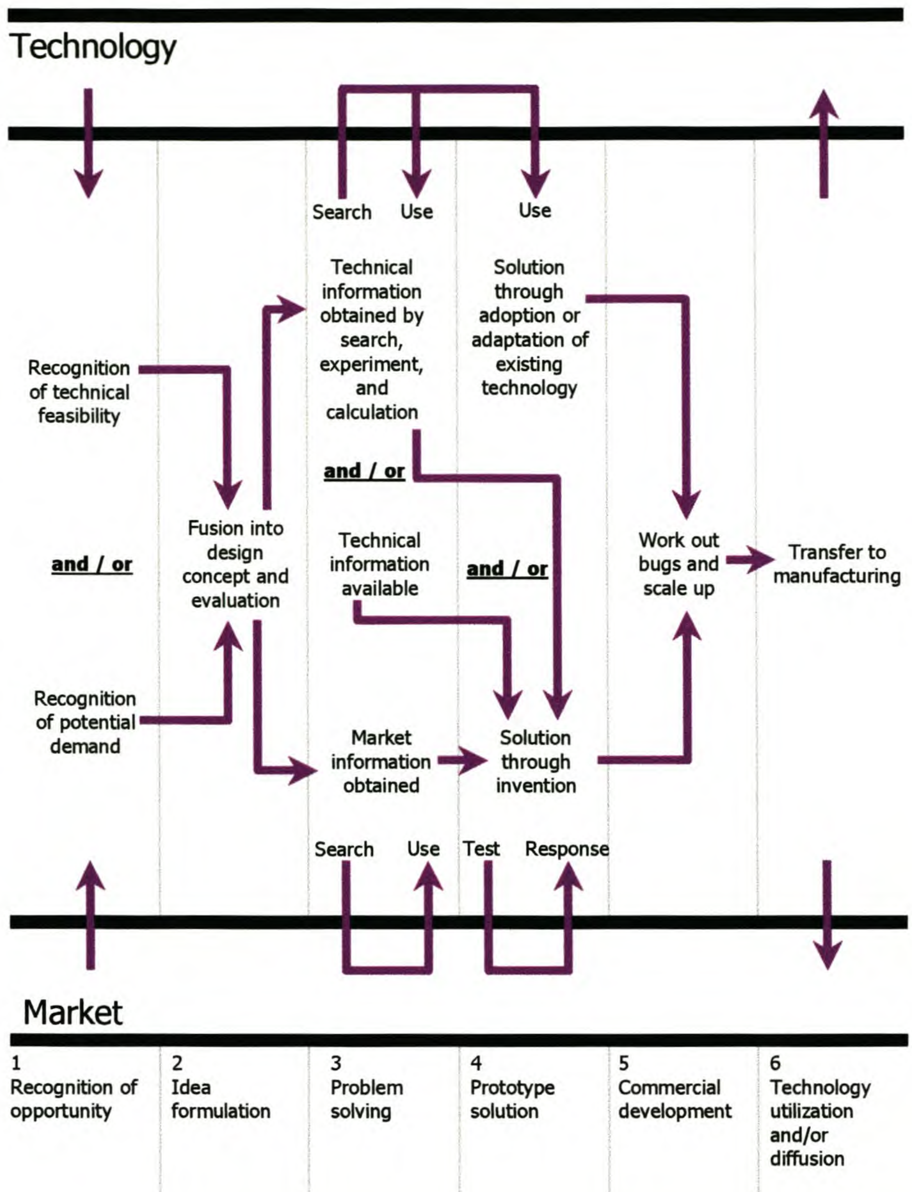


Figure 3.13: The process of technology innovation (Roberts, 1988).

The distorted perception that most innovations are successful arises to some extent from the natural tendency of both companies and individual managers to publicise successes while allowing failures to die quietly. In addition, the data needed to analyse a failure, even for an internal study, are usually difficult to quantify.

In reality, the failure rate of innovations is high. This fact reflects the intricacy and interdependence of modern advances in technology. To be successful, any attempt to introduce a technical capability must demonstrate that the capability really does offer substantial advantages. Most of the time, however, a new technology either is not enough of an improvement over the old to warrant the effort and the risk it entails, or it has problems and deficiencies that were not apparent initially. Only about one in ten R&D projects turns out to be a commercial success, with the other nine either not meeting technical or commercial objectives (Pavitt, 1990). As with a jigsaw puzzle, adding a piece to a simple two-dimensional puzzle is not difficult, but fitting a new piece into a complex, three-dimensional puzzle is (Norton and Bass, 1992).

New technology constantly chases the moving target of conventional technology, which is itself accelerated to improvement by the threat. The new technology rarely catches up. In fact, one of the most important economic benefits of innovative activity is the stimulus it gives to conventional technology. Sometimes, however, a limitation creates immense anxiety but eventually yields to creative effort and luck.

Achieving consistent, predictable, and cost effective performance requires a concerted effort to understand how and why an innovation works and to remove or find ways around its undesirable features. Understandably, potential users tend to remain sceptics until they have evidence of a technology's successful application to their own needs. Roberts (1988) underlines this through the general comment of "They should have known better." The market-pull approach, if not used carefully, becomes a meaningless tautology; by definition, innovations that succeed have found market-pull. In practice, the pull is usually no more than a barely perceptible tug, which you strain to sense and interpret.

From a managerial viewpoint, to understand the process of innovation and technology is to understand the factors that facilitate and inhibit the development of innovations. These factors include ideas, people, transactions, and context over time.

First, there is the human problem of managing attention, because people and their organisations are largely designed to focus on, harvest, and protect existing practices rather than pay attention to developing new ideas. An understanding of this issue should begin with an appreciation of the physiological limitations of human beings to pay attention to non-routine issues, and their corresponding inertial forces in organisational life. The more specialised, insulated, and stable an individual's job, the less likely the individual will recognise a need for change or to pay attention to innovative ideas. The more successful an organisation is the more difficult it is to trigger peoples' action thresholds to pay attention to new ideas, needs, and opportunities (Porter, 1990). At the group and organisational levels, the problems of inertia, conformity, and incompatible preferences are added to the above physiological limitations of human beings in managing attention. When people reach a threshold of dissatisfaction with existing conditions, they will initiate action to resolve their dissatisfaction. However, because individuals unconsciously adapt to slowly changing environments, their thresholds for action are often not triggered while they adapt over time. When situations have deteriorated to the point of actually triggering peoples' action thresholds, innovative ideas turn out to be crisis management ideas. As a result, the solutions that emerge from such "innovative" ideas are likely to be "mistakes".

Janis (1982) has shown that groups place strong conformity pressures on members who collectively conform to one another without them knowing it. A study by Pelz and Andrews (1966) found that a heterogeneous group of interdisciplinary scientists, when working together daily, became homogeneous in perspective and approach to problems in as little as three years. Groups minimise internal conflict and focus on issues that maximise consensus. "Group Think" is not only partly a product of these internal conformity pressures, but also of external conflict – "out group" conflict stimulates "in group" cohesion.

Norton and Bass (1992) explain how it is consistently underestimated how much room for improvement is left in a conventional technology. At the same time, those who take the opposite course are often criticised. The people who support evolutionary improvements are not opposed to new technology. Naturally, since they have to take the risk of being wrong and of seeing an investment prove worthless, they support the development of a technology that promises to be adequate as well as less likely to fail. Furthermore, Norton and Bass (1992) predicts that the intensification of oil and gas exploration, production in more hostile environments, enhanced recovery methods, co-generation, combined cycles, and increased attention to efficiency in use, will continue to be the most productive responses to our energy problem. Synfuels still wait in the wings, and exotic solar, ocean, thermal, and fusion technologies will be many decades in coming.

In a study on group dynamics in General Electric, Norton and Bass (1992) found that the engineering group in General Electric's large steam turbine-generator business had a well-deserved reputation for being the best in the world at what it did. The engineers were not easy to work with; they were hard-nosed, doubting, conservative, unforgiving of mistakes, and demanding. To the extent that they were resistant to change, scarred as they were from personal encounters with past misconceptions, their resistance helped minimise flawed innovations and costly mistakes. In today's complex technical environment, only the closest attention to detail and the most vigorous insistence on routines and standards make engineering design cost-effective. Instead, the programmes tend to be more like superstitious learning, recreating actions that may have little to do with previous success and nothing to do with future success. As a result, the older, larger, and more successful organisations become, the more likely they are to have a large repertoire of structures and systems which discourage innovation, while encouraging tinkering. Managers must see the process of innovation accurately, not as coloured by varied misconceptions. Although the odds are very high that any given innovation attempts will fail, companies must innovate in order to survive. The benefits of the occasional successes are enormous, not only in direct rewards to the innovator and of gains to society, but also in the ripple effects generated by the process itself. It stimulates conventional technology into improvement, stimulates adaptability to change, leads a company toward greater self-awareness of its strengths and weaknesses, and responds to one of the most powerful human drives – the urge to try something new.

Van der Ven (1986) stresses the difficulty of managing ideas into good currency so that innovative ideas are implemented and institutionalised. While the invention or conception of innovative ideas may be an individual activity, innovation (inventing and implementing new ideas) is a collective achievement of pushing and riding those ideas into good currency. The consequences of ignoring technology advances are apparent. For their well-being, all institutions in our society, particularly industry and government, must anticipate radical technology changes that sweep aside existing practices and open new opportunities – or create new problems. The company that neglects this task runs a serious risk.

Discussions that Abernathy *et al.* (1974) had with several hundred research and engineering managers have convinced him that this role is played neither widely nor well in many R&D departments. The reason is that most R&D departments are expected to concentrate on product development and refinement and new applications. They tend to keep their eyes on the technological workbench immediately before them.

There is a structural problem of managing part-whole relationships, which emerges from the proliferation of ideas, people and transactions as an innovation develops over time. Peters and Waterman (1982) dramatised this problem of part-whole relationships with an example of a product innovation which required 223 reviews and approvals among 17 standing committees in order to develop it from concept to market reality. Moreover, they state that: "The irony and the tragedy, is that each of the 223 linkages taken by itself makes perfectly good sense. Well-meaning, rational people designed each link for a reason that made sense at the time. The trouble is that the total picture as it emerged captures action like a fly in a spider's web and drains the life out of it."

The context of an innovation points to the strategic problem of institutional leadership. Innovations not only adapt to existing organisational and industrial arrangements, but they also transform the structure and practices of these environments. The strategic problem is one of creating an infrastructure that is conducive to innovation. Most innovations involve new technical and administrative components.

People become attached to ideas over time through a social-political process of pushing and riding their ideas into good currency, as Schön (1971) describes for the emergence of public policies. Figure 3.14 illustrates the process.

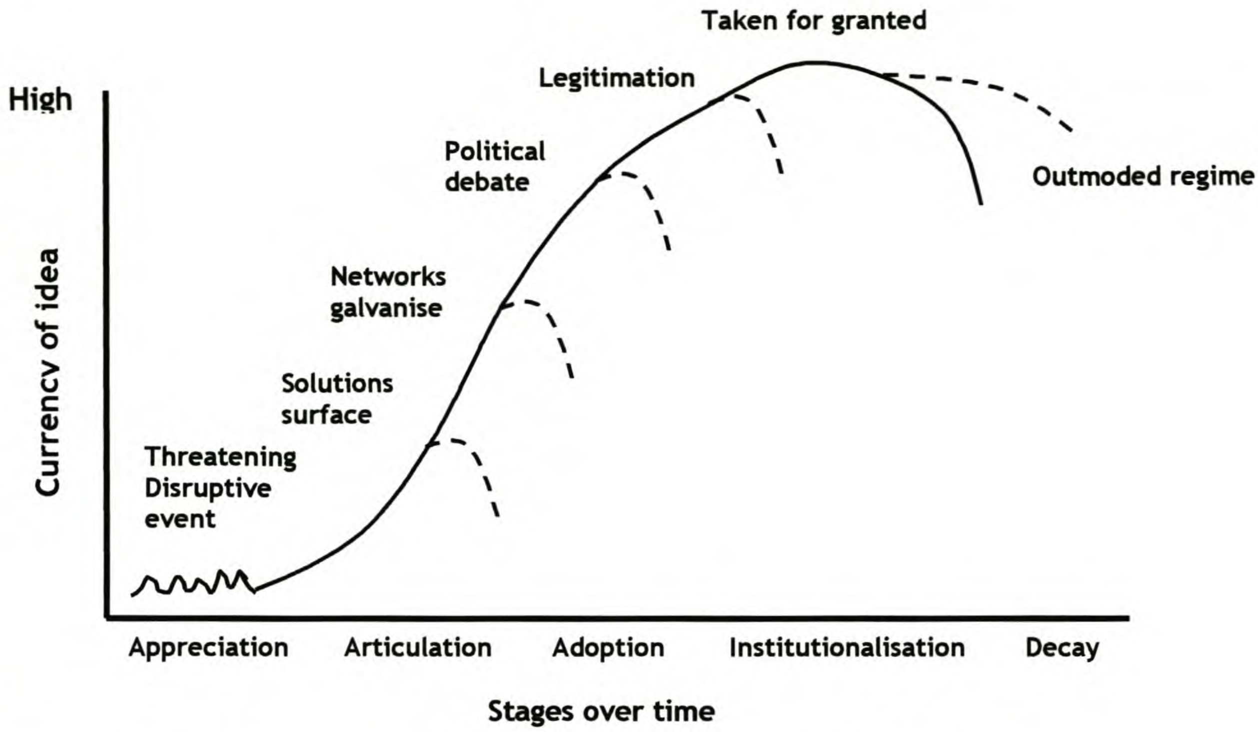


Figure 3.14: Managing life cycle of ideas into good currency (*Schön, 1971)*

There are also some basic limitations to the process that leads to inertia and premature abandonment of some ideas. First, there tends to be a short-term problem orientation in individuals and organisations, and second, a façade of demonstrating progress. This has the effect of inducing premature abandonment of ideas because even if problems are not being solved, the appearance of progress requires moving on to the next batch of problems, "old questions are not answered – they only go out of fashion". Furthermore, given the inability to escape the interdependence of problems, old problems are relabelled as new problems. As a result, and as observed by Cohen, March and Olsen (1972), decision makers have the feeling that they are always working on the same problems in somewhat different contexts, but mostly without results.

Janis (1982) states that only the vigilance pattern generally leads to decisions that meet the main criteria for sound decision making. Vigilance involves an extended search and assimilation of information, and a careful appraisal of alternatives before a choice is made. Vigilance tends to occur under conditions of moderate stress. Under conditions of no slack capacity or short-time horizons (which produce stress), the decision process will resemble crisis decision making, resulting in significant implementation errors.

However, as the discussion of managing ideas into good currency implies, innovation is not an individual activity – it is a collective achievement. Therefore, over time there is also a proliferation of people (with diverse skills, resources, and interests) who become involved in the innovation process. When a single innovative idea is expressed to others, it proliferates into multiple ideas because people have diverse frames of reference, or interpretive schemes, that filter their perceptions. Hackman (1984) supports this and states that the objective is to develop synergy in managing complexity and interdependence with an organisational design where the whole is greater than the sum of its parts. However, the whole often turns out to be less than, or a meaningless sum of the parts, because the parts do not add to, but subtract from one another.

There is a growing recognition that innovation requires a special kind of supportive leadership. This type of leadership offers a vision of what could be and gives a sense of purpose and meaning to those who would share that vision. It builds commitment, enthusiasm, and excitement. It creates a hope in the future and a belief that the world is knowable, understandable, and manageable. The collective energy that transforming leadership generates, empowers those who participate in the process. Hope leads to optimism and optimism gives energy (Roberts 1984).

To successfully manage technology, a firm should display the following attributes:

- the capacity to orchestrate and integrate functional and specialist groups for the implementation of innovations;
- the continuous questioning of the appropriateness of existing divisional markets, missions, and skills for the exploitation of technological opportunities; and
- a willingness to take the long-term view of technological accumulation within the firm (Roberts,1988).

Roberts (1988) describes the various roles for individuals in an innovative firm:

Firstly there are idea generators, the creative contributors of new insights that both initiate projects and contribute to problem solutions throughout technical projects.

Then there are the idea exploiters. There are however, significant differences between "idea-havers" and "idea-exploiters" – those who come up with ideas and those who do something with the ideas they, or someone else, have generated. This holds true whether the ideas are born in universities, government or in industry. The generally low rate of energetic pursuit of newly created R&D ideas mandates the requirement for the second key role in technical innovation-seeking activities, that of the entrepreneur or product champion. Entrepreneurs advocate and push for change and innovation. They take ideas, whether their own or others, and attempt to get them supported and adopted. Most major studies of factors affecting product success have found the active presence of a product champion to be a necessary condition for project success. A required role in effective innovative activities is the programme manager or leader, sometimes strangely called the "business innovator". They supply the support functions of planning, scheduling, monitoring and control, technical work supervision, business and financial co-ordination relating to the R&D project. Gatekeepers, or specialist communicators, are the fourth critical role identified, the link-pins who frequently bring information messages from sources outside of a project group into that group. These human bridges join technical, market and manufacturing sources of information to the potential technical users of that information. Effective "bridgers" were found to be good listeners, have depth in at least one discipline, have a wide range of interests, and be oriented towards problem solving. The final key role is that of the sponsor or coach, performed usually by a more senior person who is neither carrying out the R&D itself nor is directly and personally aggressively championing the change.

For a given technology, the advent of a new technological generation will eventually drive sales of the earlier generation to approximately zero. The scientists and engineers most closely associated with the work of innovation are painfully aware of the consequences of misconceptions about the rate, direction, and character of technological progress.

Another problem that is related to management structure and thinking, concerns time-scales. According to Norton and Bass (1992), the time for significant technological change may be 5 to10 years. Roberts (1988) believes this period could be as long as 20 to 30 years. This does not relate well to conventional 3- or 5-year corporate plans or to the 90 percent of R&D activities that he says are likely to be timed over a 3-year cycle. Also, thinking about the long-term does not always sit well with the short-term horizons of many managers, based on their own short-term job tenure perspective, the pressures of quarterly reports or the overall short-term orientations of many Western companies when compared to their Japanese rivals.

These concerns have been particularly marked in the United States, where sectors of earlier technological strength, steel, motorcars, and now electronics, are under threat from Japanese firms that spend about 30% more of their output on R&D activities than do their U.S. counterparts. As a result, there has been increased interest in the 1980's among management scholars, consultants, and practitioners in the role of technology in such matters as corporate strategy, operations management, global competition, strategic alliances, and the like (Pavitt,1990).

3.3 Forecasting

3.3.1 Definitions of technology forecasting

In paragraph 2.1.1, technology is defined as: "The entire body of methods and materials used to achieve industrial or commercial objectives".

Morris (1985) defines "forecast" as "To estimate or calculate in advance (to make) a conjecture concerning the future." Combining the ideas of technology and forecasting, a technology forecast can then be defined as a prediction of the future characteristics of useful machines, procedures, or techniques. Blackman (1973) reinforces this, who defines it as follows:
"Technology forecasting is "a quantified prediction of timing and degree of change in technological parameters, attributes, forms, capabilities, relative desirability, or needs."

Martino (1983) identifies three important points regarding technology forecasting. First, a technology forecast deals with characteristics, such as levels of performance (e.g., speed, power, or temperature). It does not have to state how these characteristics will be achieved (i.e. the forecaster is not required to invent the technology being forecast). Even though the forecaster may predict characteristics that exceed the limitations of current technical approaches, the forecast need not state how these will be achieved. Second, technology forecasting deals with useful machines, procedures, or techniques. In particular, this is intended to exclude from the domain of technology forecasting those items intended for luxury or amusement, which depend more on popular tastes than on technological capability. It does not seem possible to predict these rationally; however, the forecaster might be concerned with the means by which popular tastes will be formed, such as advertising or propaganda. Third, forecasting is a process of estimating a future event by casting forward past data. The past data is systematically combined in a predetermined way to obtain the estimate of the future. Prediction is a process of estimating a future event based on subjective considerations other than just past data; these subjective considerations need to be combined in a predetermined way. In business in general, when people speak of forecasts, they usually mean some combination of both forecasting and prediction (Adam and Ebert, 1978).

Technology assessment, a form of technology forecasting, originated in the United States, where in 1967 an "Office of Technology Assessment" was proposed to the US Congress (Tschirky, 1994).

3.3.2 The need for technology forecasting

The goal of technology forecasting has been to provide systems of logical analysis and data for predicting future technical developments and the impacts of these developments on future economic, ecological, social, and political environments (Blackman, 1973).

Technology forecasting focuses on predicting what future technologies are likely to emerge and when they are likely to be economically feasible. In an era when technological breakthrough and innovation have become the rule rather than the exception, it is extremely important that managers be able to anticipate new developments in advance. If a manager invests heavily in existing technology (such as production processes, equipment and computer systems) and this technology becomes obsolete in the near future, the company has wasted resources.

The most striking technological innovations in recent years have been in electronics, especially semi-conductors. Home computers, electronic games and sophisticated communications equipment are all evidence of the electronics explosion. Other areas of rapid innovation include lasers, synthetic fabrics and materials, construction equipment and methods, health care and robotics.

The Delphi technique and brainstorming are methods most organisations use in technology forecasting. Given the increasing importance of technology and the rapid pace of technology innovation, it follows that managers will grow increasingly concerned with technology forecasting in the years to come (Twiss, 1992).

The question, "Why forecast technology?" has a false implication. It implies that there is a choice between forecasting and not forecasting. However, forecasting technology is no more avoidable than is forecasting the weather. All people implicitly forecast the weather by their choice of whether to wear a raincoat or carry an umbrella. Any individual, organisation, or nation that can be affected by technological change, inevitably engages in forecasting technology with every decision that allocates resources to particular purposes. A change in technology may completely invalidate a particular decision about allocating resources. Every decision, then, carries within itself the forecast that technology will either not change at all or will change in such a way as to make the decision a good one (Martino, 1983).

In the face of the increasing risks growing out of technology decisions, a significantly higher demand for knowledge concerning technology forecasting and assessment is becoming apparent for the future (Tschirky, 1994). Risk, which arises because of uncertainty, has two dimensions. The first of these is a result of an event which no one could have been expected to foresee – a scientific breakthrough, the outbreak of war, a natural disaster or the collapse of a bank, for example. Sometimes it might have been possible to anticipate these events, but because of their nature they are quite impossible to forecast when they might occur, e.g. a nuclear power plant or oilrig disaster, an earthquake, or genetic engineering legislation. In this category, forecasting can be of little or no direct assistance to the decision maker. The second, and most important area of uncertainty, is associated with the steady evolution of established trends. If the trend can be identified and its future level of performance related to a time scale, it follows that it should be possible to use it for forecasting. This pre-supposes that the trend follows a steady path, in other words, it is possible to identify a pattern. Fortunately, most of the phenomena of direct interest to the technologist do exhibit such patterns.

As a consequence, the business risk (e.g. the possibility of financial loss through taking a poor decision) is correspondingly reduced (Twiss, 1992).

Given that technology forecasting is inevitable, however, there is still the issue of what specific reasons people have for making technology forecasts. In reality, people make technology forecasts for the same reasons that they make other forecasts:

- to maximise gain from events external to the organisation;
- to maximise gain from events that are the result of actions taken by the organisation;
- to minimise loss associated with uncontrollable events external to the organisation;
- to offset the actions of competitive or hostile organisations;
- to forecast demand for purposes of production and/or inventory control;
- to forecast demand for facilities and for capital planning;
- to forecast demand to assure adequate staffing;
- to develop administrative plans and policy internal to an organisation (e.g. personnel or budget); and
- to develop policies to apply to people who are not part of the organisation.

The following are specific roles that technology forecasts play in improving the quality of decisions as described by Martino (1983):

- It identifies limits beyond which it is not possible to go.
- It establishes feasible rates of progress, so that the plan can be made to take full advantage of such rates and that the plan does not demand an impossible rate of progress.
- It describes the alternatives that can be chosen.
- It indicates possibilities that might be achieved, if desired.
- It provides a reference standard for the plan. The plan can thus be compared with the forecast at any later time to determine whether it can still be fulfilled or whether, because of changes in the forecast, the plan must be revised.
- It furnishes warning signals, which can alert the decision maker that it will not be possible to continue the present activities.

When forecasting, it is important not to overemphasise the possible future implication of potentially new technologies (Rosenberg, 1995).

3.3.3 Alternatives to forecasting

The definition of a forecast, as estimating or calculating in advance, implies some degree of rationality and analysis of data. However, there are many "alternatives" to rational and analytic forecasting. Most of these alternatives are widely used for the same purpose as forecasts, and are summarised by Martino (1983) as follows:

a) No forecast

This alternative means facing the future blindfolded. If taken literally, it means that no attempt is made to determine what the future will be like and that decisions are made without any regard whatsoever to their future consequences, be they favourable or unfavourable. It should be clear that any organisation operating on this basis will not survive. Even if the environment is unchanging, most decisions will be wrong, since they will not even take into account a forecast of the constancy of the environment. If the environment is changing rapidly, disaster may come even more quickly, since a decision that is right for a short time may be rendered inappropriate in the longer run. In most cases, however, the concept of "no forecast" is not meant literally but is really intended to mean a forecast of constancy or negligible rate of change. Thus, when a decision-maker claims not to believe in or use technology forecasts, what the decision-maker really means is that he or she has assumed an unchanging technology. The decisions are made on the basis of a forecast that the technology in existence at the time during which these decisions have their impact will be the same as the technology of today. Thus, this is really not an alternative to forecasting but a very specific, though implicit, forecast.

b) Anything can happen

This represents the attitude that the future is a complete gamble, that nothing can be done to influence it in a desired direction, and that there is no point therefore, in attempting to anticipate it. It is doubtful if there is any decision maker who runs his or her personal life this way. Even decision makers who claim to have this attitude are still likely to take a raincoat on cloudy days. Therefore, if they pretend to adopt this attitude toward their professional decisions, it really amounts to a cover for something else – perhaps an attempt to avoid the effort of thinking through the implications of a forecast. Obviously, decision makers who really act on the basis of this attitude are headed for trouble. In particular, they may find their organisations unable to withstand the competition from other organisations that do attempt to anticipate the future through rational means. An organisation run on this basis can only be short-lived.

c) The glorious past

This represents an attitude that looks to the past and ignores the future. Many organisations can point to significant achievements at some time or the other in the past. Their very survival over an extended period indicates that they have done the right things. Unfortunately, when conditions change, it is very unlikely that the policies and decisions that led to their past success will continue to be relevant. Stubbornly clinging to visions of the glorious past, on the assumption that the glorious past guarantees a glorious future, is a certain road to disaster. In short, an organisation that concentrates on its past instead of the future can end up only in becoming a museum piece.

d) Window-blind forecasting

This involves the attitude that technology moves on a fixed track, like an old-fashioned roller window blind, and that the only direction is up. This attitude is encapsulated in expressions such as "higher, faster, and further," or "bigger and better"; it assumes that the future will be like the past, only more so. While this attitude does at least recognise that changes do take place and is, therefore, somewhat better than the preceding alternatives, it fails to recognise that there are other directions besides up. A particular technical approach, for instance, may come to a halt or move sideways if another technical approach supersedes it. An organisation that depends on window-blind forecasting will sooner or later be taken by surprise as some unanticipated technological change brings an end to the track the organisation was following.

e) Crisis action

This can best be described as "pushing the panic button." It consists of waiting until the problem or crisis has arrived and then taking some immediate action to attempt to alleviate the impact of the crisis. Over the long-term, crisis action means that the organisation is not making any net progress toward its goals. As a result of expedient responses to crises, it may only be zigzagging instead of proceeding directly toward an objective. Furthermore, this alternative is based on the assumption that there will be time to respond effectively after a crisis has arrived. If this assumption proves false in a specific crisis, the organisation will fail to survive. Finally, this alternative ignores the fact that had a proper forecast been used, the crisis might have been avoided completely. Hence, although this approach is sometimes used, this is not really an acceptable alternative to proper forecasting.

f) Genius forecasting

This is not really an alternative to forecasting since it does involve the preparation of a forecast. However, it is an alternative to the use of rational and explicit methods for obtaining forecasts. This method consists of finding a "genius" and asking him or her for an intuitive forecast. It must be recognised that many "genius forecasts" made in the past have been successful. Unfortunately, there have also been many such forecasts so wide off the mark as to be useless. The shortcomings of genius forecasting are that it is impossible to teach, expensive to learn, and allows no opportunity for review by others. Obviously, there is no fool-proof way of obtaining a genius, and even if a genius has been located, his or her forecast cannot be checked by anyone else, even by another genius. It must be taken on faith. It may be that in some cases there is no alternative to a genius forecast; however, it should be clear that where rational and explicit methods are available, they are much preferable. In fact, rational and explicit methods relieve the decision maker of the burden of ferreting out geniuses.

Technology has been the major force in fashioning the world we live in. Within our society technologists make a vital contribution to corporate success. The role of technology is to add new dimensions to human capability by enabling us to accomplish tasks or satisfy needs which were not possible in the past. Thus we live in a continuum of progress' starting in the past and stretching through the present and into the future. However, technological progress is not inevitable. It is brought about by the decisions of individuals who apply the accumulated knowledge of the past to the needs of the future. No progress will occur without decisions, nor can those decisions be taken in a vacuum. They must be translated into the actions, which require the investment of scarce resources if the advances are to be made.

However, those funds will not be made available unless there are sound grounds for anticipating that they will yield future benefits (Twiss, 1992).

3.3.4 Factors affecting forecasts

Predictions by some well-known individuals made in the past were:

- "Computers in the future may weigh no more than 1.5 tons." *Popular Mechanics* magazine 1949, forecasting the relentless march of science.
- "I think there is a world market for, maybe, five computers." Thomas Watson, chairman of IBM, 1943.
- "I have travelled the length and breadth of this country and talked with the best people, and I can assure you that data processing is a fad that won't last out the year." The editor in charge of business books for Prentice Hall, 1957.
- "But what is it good for?" Engineer at the Advanced Computing Systems Division of IBM, 1968, commenting on the microchip.
- "There's not reason anyone would want a computer in the home." Ken Olson, President, Chairman and founder of Digital Equipment Corporation, 1977.
- "640K ought to be enough for anybody." Bill Gates, 1981.
  (Clarke, 2000).

When comparing predictions by Americans between 1890 and 1940 of future technological changes and the effects of those changes to the actual outcomes, then less than half of the predictions have been fulfilled or are in the process of being fulfilled. Wise (1976) evaluated a sample of 1556 predictions for accuracy. His results were as follows: predictions fulfilled: 499 (32%); predictions in progress: 121 (8%); predictions not proven: 420 (27%); and predictions refuted: 516 (33%). The accuracy of predictions appears at best weakly related to general technical expertise, and unrelated to specific expertise. One expert (or non-expert) appears to be as good a predictor as another. Predictions of continuing *status quo* are not significantly more or less accurate than predictions of change. Predictions of the effects of technology are significantly less accurate than predictions of technological changes.

Forecasting errors could arise from five main causes:

- Factors which could not have been foreseen when the forecast was made.
- Deficiencies in the data available for making the forecast.
- Inappropriate assumptions.
- Faulty logic incorporated into the choice of the technique.
- Failures in the use and interpretation of information in the forecasting process including poor judgment in relation to subjective factors.

The factors behind these causes of inaccuracy are primarily divided into those related to the environment within which the forecast is made and personal factors related to the forecaster.

3.3.4.1 Environmental factors

It deserves emphasis that today environmental factors are becoming a stronger source of pressure for change (Bright, 1978).

a) *Technological factors*

A common failing of forecasters is to ignore developments in other fields, or other countries, that may supersede the technology to be forecast. Another common failing of forecasters is to ignore the impingement of one technology on another (Martino, 1983). Twiss (1992) believes that in long-term forecasting the most common concern of technologies is the identification of big messages.

Technology rarely achieves major economic impact until it is adopted on a significant scale, so there is ample warning. Production problems and the time needed for diffusion of radical new ideas delay the major economic impact for at least 5 and maybe even 20 years (Bright, 1978). Bright (1963) stresses the importance for the businessman to have a keen sensitivity, awareness, and receptivity to technological change as a major environmental force, which he can employ, and to which he must respond. In many businesses, it will be far and away the most important force. The concept of formal technology forecasting may seem extremely difficult; nonetheless, we must somehow anticipate technological progress. It is an evolving phenomenon having sources, causes, directions, rates of progress, and successive sets of effects. If we can learn to follow this progress and its interaction with other forces in the business environment, we can better anticipate the probable economic and business consequences, and take useful actions.

The view that technological change has such a powerful role in shaping competition within industries has been increasingly stressed in the past (Freeman, 1982; Porter, 1985; Pavitt, 1990). This makes forecasting the path of technological evolution extremely important in allowing firms to anticipate technological change and thereby improve their competitive positions. It should be possible to monitor the environment to detect the coming, progress, and the consequences of significant technological advances. Bright (1978) includes four activities required in monitoring:

- Searching the environment for signals that may be forerunners of significant technological change.
- Identify the possible consequences.
- Choosing the parameters, policies, events, and decisions that should be observed and followed to verify the true speed and direction of technology and the effects of employing it.
- Presenting the data from the foregoing steps in a timely and appropriate manner for management's use in decisions about the organisation's reaction.

b) Economic factors

Typical failures here arise from an over-optimistic estimate of the acceptance of some innovation or an over-pessimistic estimate of the acceptance of some innovation or an over-pessimistic estimate of the problems of introducing it (Martino, 1983). When attempting to impose a "best fit" curve, it will be applied to points exhibiting what is often a substantial amount of scatter. In these circumstances it might be possible to fit a number of curves of different mathematical form to the same data points. When extrapolated, these curves would lead to significant variations in the resulting forecasts. As a general rule, this procedure is to be avoided.

The cyclic characteristic of much economic data, for example the five-year business cycle, must be considered in economic forecasting. Although the exact timing of each change of direction and its peak-to-peak amplitude may be difficult to define precisely, this is still the most fundamental relationship underlying most economic forecasting. In particular, it directs attention to the fact that any short-term trend contains a large cyclical element (Twiss, 1992).

c) Political factors

The traditional analytical procedures used by business and government evaluate only factors in the technical and economical environments. But often the key events – changing values and relationships that determine the ultimate significance of the technology and its timing – lie in social and political spheres. Changes in the political environment can have a significant impact on technological progress. This may arise from the creation of new agencies or from the replacement of one official having one set of views by another having different views (Martino, 1983).

d) Social factors

Martino (1983) highlights the fact that a major source of error in past forecasts has arisen from the failure to take into account changes within society, particularly population growth, changes in the age distribution, and the growth of affluence. In addition, the impact of special interest groups within society, such as labour unions, conservation groups, and consumer organisations, must be taken into account. Population trends are a prime source of signals relevant to the 10 to 30 year horizon. Hindsight reviews of technological forecasts suggest that population figures are very often neglected and unappreciated as criteria for assessing the economic significance of technological changes.

Bright (1978) says the following regarding social attitudes: "When assessing social attitudes, the manager or analyst must not apply his own value system. He must keep in mind that their influence on technological progress stems from the attitudes that they create, and not from the accuracy or completeness of their statements".

e) Cultural factors

Changes in the values subscribed to by society can have an impact on a forecast. Martino (1983) uses the example of the decade 1960 to 1970, which saw a steady shift in the values of the youth in the United States. Many forecasts made during this period, based on this shift were also incorrect, as another shift began in the 1980's. The forecaster must take social value shifts into account in his or her forecast and must be aware of the fact that a forecast will be invalidated by a subsequent shift in such values.

f) Intellectual factors

In the short-term, the values of the intellectual leadership may be more important than those of society at large, since the former are likely to have more influence on the course of the development of technology. Conversely, over the long-term, the attitudes of society at large may have more influence than those of the intellectual leaders, who cannot remain leaders indefinitely if they have no followers.

g) Religious-ethical factors

At the present time, it seems unlikely that any major religious group could have a large-scale impact on technological advance, at least on doctrinal grounds. However, it is quite possible that at some time in the future, religious, ethical, and professional groups, together or separately, may come to have an impact on technological advance by raising moral questions about the proper goals and objectives for humanity.

h) Ecological factors

This dimension is likely to have a growing impact on the course of development of technology and is therefore of considerable importance to the technology forecaster (Martino, 1983).

3.3.4.2 Personal factors that affect forecasts

To the extent that a forecaster can identify and make allowances for these personal factors, the result will be that the forecast will be more useful, and if not self-defeating, more likely to come true. A summary of Martino's (1983) views on the subject are discussed below.

a) Vested interest

This problem arises when forecasters have a personal interest in an organisation or a particular way of doing things that might be threatened by a change in technology. A person may have spent his professional life with a particular organisation or industry or may have favourable associations with a particular group of people or industry or a personal commitment to a specific organisation or a way of life. In any of these cases a forecast, which appears to threaten any of these interests, may be suppressed.

b) Narrow focus on a single technology or technical approach

This error is committed when the forecaster looks at only one specific technology or technical approach. It differs from the previous one in that the narrow focus arises from the forecaster's experience or training, rather than from a vested interest. Because of experience or training, the forecaster is conditioned to think only in terms of one type of solution. This could lead the forecaster to make a "window blind" forecast.

c) Commitment to a previous position

This situation arises when a forecaster has prepared a forecast on a particular topic in the past and is asked to take another look at the same topic or a related one. As a result of the earlier forecast, the forecaster may be unwilling to make any alterations, even in the face of new information. A dislike of the source of a new innovation is another example of this kind of error. A forecaster may have some reason to dislike an organisation or individual from where the innovation originated and choose to ignore this in the forecast.

d) Over compensation

This happens when the forecaster will go out of his way to prevent a strong desire for a specific outcome from distorting the forecast. As a result, the forecast is distorted in the opposite direction. Even though this distortion is just as bad as the vested interest distortion, it is harder to detect because it seems like the forecaster is trying to be "fair".

e) Giving excessive weight to recent evidence

It is only natural to emphasise recent events more than those of a distant past, even when the latter may contradict the recent events. If, for instance, some activity has been following a long-term rising trend, but has recently had a downward fluctuation, similar to downward fluctuations in the past, the forecaster may give more weight to the recent downward fluctuation, at the expense of the true long-term trend. Such a decision can only be made if there is evidence to show that there is a definite departure from the past long-term trend.

The other generic error is to under estimate the scope of change brought about by a significant new development. Most significant forecasts should be supported by convergent trends. Rarely does a single driver lead to big change. It is the simultaneous operation of several trends that has the most striking outcome (Coates, 1995).

f) Excessive emphasis on the troubles of the recent past

This is a more acute form of the previous deficiency. Serious troubles are likely to make a deep impression, predisposing the forecaster toward a particular outlook. Troubles may come to be viewed as permanent, instead of as a temporary phase that may, but need not recur.

g) Unpleasant course of action

Sometimes the course of action that seems to be made necessary by the forecast will appear so unpleasant that the forecaster avoids making the forecast in the hope of thereby avoiding the necessity for the required actions.

h) Systematic optimism-pessimism

There is a systematic shift from optimism to pessimism as the time and length of the forecast increases. In the short-run forecasters are more optimistic, while pessimism sets in as time rolls on. Although this affects not all forecasters, it is useful to be aware of it and thereby have a better chance of avoiding them.

3.3.4.3 The effect of core assumptions

Ascher (1978) has shown that one of the most serious sources of error in forecasts is what he has called "core assumptions." These are the underlying assumptions made by the forecaster, regarding the subject area to be forecast. Once the core assumptions are made, selection of the forecasting method is usually obvious or trivial. Coates (1995) states that the forecast must make its assumptions explicit and clear.

Many people educated within a strict theoretical discipline believe that the inability to measure and express all phenomena in quantitative terms is synonymous with ignorance. Technologists and economists are particularly prone to this erroneous view. Therefore, there is a tendency to ignore any factors that are "woolly" or incapable of numerical expression. But a brief reflection on the most important personal decisions we take, the choice of a wife or husband, the purchase of a car or house, shows that in reality, the quantitative element is only part, often a small part, of the totality of the considerations to be taken into account. Different people would make different decisions in the same circumstances.

Twiss (1992) refers to an examination of the history of technology innovations, revealing a catalogue of commercial failures – Concorde, the video telephone, the Wankel engine, synthetic tobacco, the Betamax video recording system. With the benefit of hindsight, the reasons for these failures are glaringly obvious. Yet it is rare for the technological performance to fall far short of the initial specification. The failures occurred in the market place for reasons that in many cases could and should have been identified before the development commenced. At that time the signals may have been weak and rejected after careful analysis. More often, however, they were strong but were either not identified or were ignored. Enthusiasm for the technology blinded the innovators to the wider issues on which commercial success would depend. Technology progresses in response to outside pressures, economic, social and political as well as technological. These manifest themselves in the market place and through legislation. Thus, a forecasting system for technical decisions must incorporate all the causal factors.

IBM's Thomas Watson Sr. was not necessarily far off the mark when he concluded that the future market for the computer was extremely limited, if one thinks of the computer in the form in which it existed immediately after the Second World War. The first electronic digital computer, the ENIAC, was more than 100 feet long, filled a huge room, and contained no fewer than 18,000 vacuum tubes. Any device that has to rely on the simultaneous working of 18,000 vacuum tubes is bound to be notoriously unreliable. Watson's "failure" in prediction was a failure to anticipate the demand for computers after they had been made very much smaller, cheaper, more reliable, and faster by many orders of magnitude (Rosenberg, 1995).

A signal usually has a number of possible implications, so all of them must be followed until it becomes clear which are the correct ones. There are many false and misleading signals in the environment, and it is hard to isolate the valid signals from the "noise". At times, the role of an individual is decisive; an able and determined man in a key position can dominate the direction or the timing of technology. Many technological refinements are offered to solve some problems, and most never materialise in economic form. There are more contenders than winners. Therefore, we must monitor many developments, realising that only time will tell which is the truly significant technology (Bright, 1978).

No responsible futurist today approaches his or her work without the concept of alternative futures and without the sense of probabilistic or contingent outcomes. The world is so complex, and the forces at play so numerous, that to talk about the future simply doesn't make sense. One has to look at the system under consideration and recognise that from today forward, it can evolve in a variety of different ways. The farther out one looks, the more divergent those alternatives become. More troublesome are the social, political, economic, and cultural assumptions that are easily ignored, but often unstable. One generic error is to anticipate that the pace of change will be faster than it actually is. This tends to be associated with inventors, advocates, marketeers, ideologues, and other people with a strong psychological or economic stake in seeing change come quickly (Coates, 1995).

Insight is the most important human attribute in establishing the qualitative element of the forecast. It must be stressed that forecasting must not become a mechanistic procedure. Largely, it consists of looking for clues to the future and thus might be likened to detective work. The good forecaster uses his experience, his technological knowledge and his ability to form relationships between wide ranges of developments. This demands high calibre minds. It combines divergent thinking with an element of creativity. If a factor is real, one cannot afford to ignore it. If it cannot be measured and expressed in a factual numerical form, we must find some other way of considering it. It represents one's own view of the direction and magnitude of some identified factor. It must not be forgotten that the sole purpose of forecasting is to aid in the making of decisions (Twiss, 1992).

3.3.5 Overview of forecasting approaches and techniques

3.3.5.1 Approaches to forecasting

It would be a mistake to think that the approaches used by technological forecasters are unique to that application area and are somehow different from the approaches used in other application areas. In reality, there is a great deal of similarity among the forecasting approaches used in all application areas. Two schools of thought in approaching a forecast are discussed below. Martino (1983) identifies four basic categories of forecasting that are used by all forecasters. Regardless of the area of application, all forecasters use variations and combinations of the following four basic categories:

a) Extrapolation

In this method, the forecaster extends or projects a pattern that has been found in the past. The forecaster starts with a time series of past data about the entity to be forecast. For instance, a technological forecaster who was attempting to forecast future aircraft speed would obtain a time series of aircraft speed records. The forecaster then attempts to find a pattern in this historical data. The typical kinds of patterns found may be trends (technological and economic data) or cycles (weather data). Once a pattern is found, it is extended to the future to obtain the forecast. The basic assumption behind forecasting by extrapolation is that the past of a time series contains all the information needed to forecast the future of that same series.

b) Leading indicators

In this method, the forecaster uses one time series to obtain information about the future behaviour of another time series. For instance, a falling barometer often precedes rain. A weather forecaster, thus, uses a "turning point" in the time series of barometric pressure to forecast a future turning point for precipitation. The basic assumption behind forecasting by leading indicators is that the time series of interest shows the same behaviour as another time series, the leading indicator, but with a known time lag. Thus, what the leading indicator is doing today will be matched by the time series of interest at a specific time in the future.

c) Causal models

Both extrapolation and leading indicators require only finding of a correlation between past and future. It is not necessary to know anything about the causal factors that make the future follow the pattern revealed by the past. For instance, the forecaster using a leading indicator does not need to know why the leader and follower behave in that fashion. Causal models, as implied by the name, incorporate information about cause and effect. A forecast of a solar eclipse, for instance, is based on a causal relationship, involving some fundamental laws of physics. The assumption behind the use of causal models for forecasting is that the cause-effect linkages in the topic of interest are known and can be expressed mathematically or in some similar fashion (e.g. a mechanical model).

d) Probabilistic methods

In the preceding three methods of forecasting, a given set of data (past time series, leading indicator series, and equations of the model) produces a point estimate of future conditions. Given past and present conditions, there is exactly one possible value for the future of the parameter to be forecast. Probabilistic methods differ from the preceding three in that, instead of producing a single-valued forecast, they produce a probability distribution over a range of possible values. Some weather forecasts are now given in this fashion. The probability of rain tomorrow may be stated as, for instance, 30 percent. This means that over the range of possible outcomes, rain and no-rain, the associated probabilities are 30 and 70 percent, respectively. Scenario analysis is a variation of a probabilistic method – a technique that has gained popularity over recent years.

In reality, these four methods are often used in combination. The point that must be remembered, however, is that there are only four basic methods of forecasting. The differences found in different application areas arise primarily from differences in the type of data available and the uses to which the forecasts will be put. The outcome is that the basic methods are used differently or are combined differently. For instance, economic data, such as prices, come at regular intervals (weekly, monthly). Technological data do not come at regular intervals. Hence, although both economists and technological forecasters use extrapolation, the specific techniques they use to extrapolate their data differ because of this fundamental difference in the nature of the data.

A second school of thought, as described by Twiss (1992) distinguishes between two categories of forecasting, namely deterministic and normative.

e) Deterministic techniques of forecasting

This is constructed on the basis that all the high probability events will occur. It yields a unique view of the future that leads to clear decisions. It is apparent that such a forecast is vulnerable to the uncertainties, which have been ignored, or to the impact of weak signals which have become significant.

These difficulties can be overcome, to some extent, by supplementing the forecast with a sensitivity analysis. This indicates the significance of any changes from the assumed conditions. In effect, this approach states "this is our best forecast under the stated assumptions but if we are wrong these are the consequences of the errors". It will also indicate those issues to which the accuracy of the forecast is most sensitive, thereby highlighting the need for close and continuous monitoring.

f) Normative techniques of forecasting

The future is not merely an extension of the past. Fundamental changes occur in society, industry, companies and individuals as a result of the introduction of entirely new types of products utilising a technology or combination of technologies, which were not previously available. Conversely, the needs of the market are influenced by developments in the wider environment. The interactions between these two streams create the potential for changes that would not be apparent from a study confined to extrapolation.

Whilst some of these advances will eventually lead to trends, which lend themselves to extrapolative analysis, the occurrence of discontinuities must not be ignored. Such events are most likely to happen in the social, economic and political rather than the technological environments. Nevertheless, their impact on the competitive potential of a technology can be considerable and must be explicitly taken into account within the forecasting process.

Because these developments have yet to occur, there is little or no hard information available to the forecaster. This means that the initial stages of the investigation must, of necessity, be speculative, but this speculation must be based on sound judgment and the insights of the best minds available if it is to be of value. This is what is described as "casting the mind forward" as the characteristic of a normative approach. It is an attempt to identify what might happen based upon postulated advances that have yet to occur (Twiss, 1992).

3.3.5.2 Forecasting techniques

There is an exhaustive list of forecasting techniques available today, from very simple to extremely complex, depending on the needs of the forecaster. What is important is to consider both deterministic and normative techniques and to then select the most appropriate methods for the specific need. Three deterministic and eight normative techniques are selected for study. The techniques selected are those that could contribute to the development of the Forest Engineering forecasting method, developed in Chapter 4. Table 3.2 summarises the techniques studied.

Table 3.2: Forecasting techniques considered for the development of the forecasting method

Forecasting Technique	Form of Forecast	Relevant Forest Engineering variable, which could be forecast
Time series	Deterministic	Fuel trends, labour cost trends, machine trends
S-curve of progress	Deterministic	Curve of specific machine and equipment types
Fisher-Pry	Deterministic	Substitution of one machine type by another
Expert judgment	Normative	Determination of relevant value chain configurations to be forecast
The Delphi technique	Normative	Determination of future technological developments in Forest Engineering
Cross-impact analysis	Normative	Determination of the high cross-impact change drivers in the Forest Engineering value chain
Pareto analysis	Normative	Determination of the few core changes in the Forest Engineering value chain
Benchmarking	Normative	Cost comparisons of various systems in various geographic regions, to guide the forecaster in selecting the appropriate value chains
Brainstorming	Normative	Creative technique, which can be used in various aspects of the forecast to determine key influencing factors
Scenario building	Normative	Allows alternative views of the future value chain to be forecasted. Used in combination with other techniques
Environmental Scanning	Normative	Increases understanding of the process of change in the Forest Engineering environment.

a) Time series

Time series of technical parameters and figures of merit are very suggestive when projected into the future. For example, the increase in the number of electrical circuits per unit of space or area in solid-state electronic systems points to a coming compression of system size to at least 1/100th of the size of the 1960 circuitry. Meanwhile, circuit cost is also declining exponentially. Devices employing electronics will become much smaller, more portable, cheaper, and more reliable, and hence will gain more widespread use.

The forecast of technical capabilities, made several years ago, has proved to be reasonably accurate. The forecasting curves generated tell the electronics equipment manufacturer that:

- Large-scale cost and size reductions in the equipment will lie ahead.
- Electronic products in almost any present configuration will be rapidly and continuously made obsolete over the next five to ten years.
- A new product in this field must be exploited very quickly, since its market life will probably be short.
- The wisdom of Solomon or the gambling instincts of an oil-well wildcatter will be needed, at times, to set production and marketing policy and tactics in this environment of rapid product change (Bright, 1978).

Wherever possible, the aim of the forecaster is to be able to produce a graph, which represents past growth along an established pattern and extend it into the future. In order to do this, one must:

- Decide the parameter to plot on the vertical axis. The horizontal axis is always time.
- Plot data points from the past.
- Decide the appropriate growth patterns to use; where they occur in combination, their individual effects must be disaggregated. In the case of an S-curve, it is also necessary to establish the upper limit to which the curve is asymptotic.
- Apply the pattern(s) to the data points.
- Extended into the future.

Time series forecasts usually apply regression equations. This technique is used in the S-curve and Fisher-Pry techniques and is therefore not discussed any further in this paragraph.

b) The S-curve of progress

The forecaster has one great advantage over the scientific experimenter. Historical experience and logic indicate what shape of curve should be fitted. In other words, there are patterns that can be identified and used. Twiss (1992) describes 4 broad categories of patterns of curves, which exist, as illustrated in Figure 3.15. These are S-curves, cycles, steady growth or decay, and discontinuities. All the phenomena the forecaster needs to study exhibit one, or a combination, of these patterns. Technological and market growth characteristically exhibit an S or logistic growth pattern. Cycles are regular patterns that repeat themselves at periodic intervals.

The growth of a large number of technologies has shown a definite pattern. When a graph of performance, measured against a technological parameter, is plotted against time, an S-curve is obtained. This is also referred to as a logistic graph (Figure 3.15a).

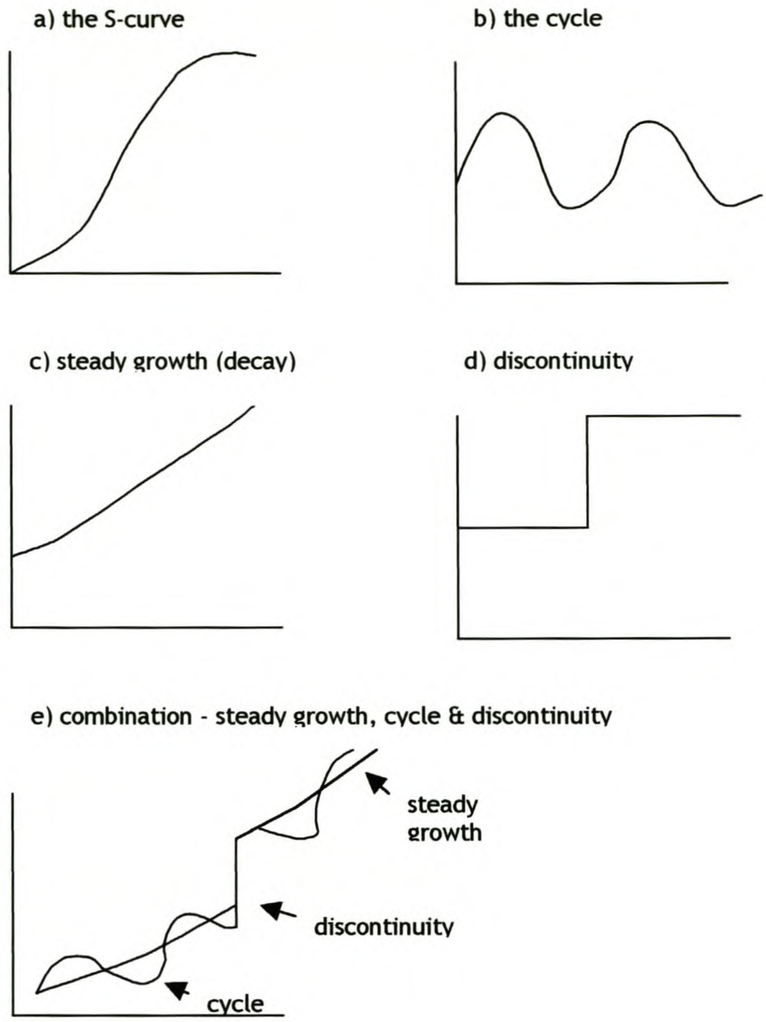


Figure 3.15: Patterns of growth (Twiss, 1992)

It can be assumed that newer technologies will exhibit the same pattern. If data is available for a technology, for a partly established curve, then it is assumed that it will continue to grow along the S-curve. This rationale is applicable to all exploratory forecasting methods. It must be stressed that although the S-curve follows the same pattern as the industry life cycle, it is fundamentally different in its application. Where the industry life cycle is only a conceptual diagram, the S-curve is an explicit graph, with explicit results.

The S-curve has 3 stages: incubation, rapid growth and maturity. This curve is similar to the industry life cycle, discussed earlier in this Chapter and need not be repeated here.

The use of S-curves should focus only on technologies which don't exist, or which are in the process of development. If the technology is in a very early stage of evolution, it is difficult to develop the curve due to the absence of sufficient data points. Here the forecaster must rely upon informed judgment. As more data becomes available over time, the shape of the curve can be adapted to supply an industry with the necessary tools to make informed decisions regarding the technology.

The greatest advantage of the S-curve is that it forces consideration of what is going to happen in the future, rather than to use judgment based on what has happened in the past. The human mind does dot naturally adopt an S-shaped thought pattern.

About halfway through the development cycle, a new technology, with a higher limit may emerge. In such a case, the old technology is doomed, no matter how great the investment. This is often ignored by industries, an example being the replacement of vinyl records and tapes by compact discs. The most important benefit derived from an S-curve is that the approach to the natural limit of a technology can be recognised.

Even though the technological parameter to be used in drawing the s-curve may be obvious, the forecaster may be too involved in the subject to recognise the true feature required of the product by the end user: for example, the cost per passenger to evaluate jet engines, as opposed to specific fuel consumption.

The procedure to draw the S-curve can be summarised as follows:

- Identify the appropriate market attribute for the product or the system in which it is embedded.
- Determine the technological parameter(s) by which the attribute can be measured.
- Collect data for the past progress of this parameter over time.
- Establish the natural/physical limit for the parameter using the technology being forecast.
- Fit an S-curve to the data, which becomes asymptotic at the limiting level.

- Consider events and other trends, which may affect the future development of the technology and thereby influence the shape of the curve, e.g. the emergence of a new technology, or other factor, which might affect the funding necessary to drive the advance.

The formula for the logistic curve is:

$$p = \frac{L}{1 + ae^{-bt}}$$

where p = value of the technological parameter

t = time (date)

L = the natural limit

a and b are constants

It is also possible to plot the S-curve by making the following transformation:

$$L = p(1 + a\,e^{-bt})$$

$$\frac{L}{p} - 1 = a\,e^{-bt}$$

$$\log\left(\frac{L}{p} - 1\right) = \log a + bt$$

Therefore if (*L/p-1*) is plotted on the y-axis against time, a straight line will be obtained since log a is a constant (Figure 3.16).

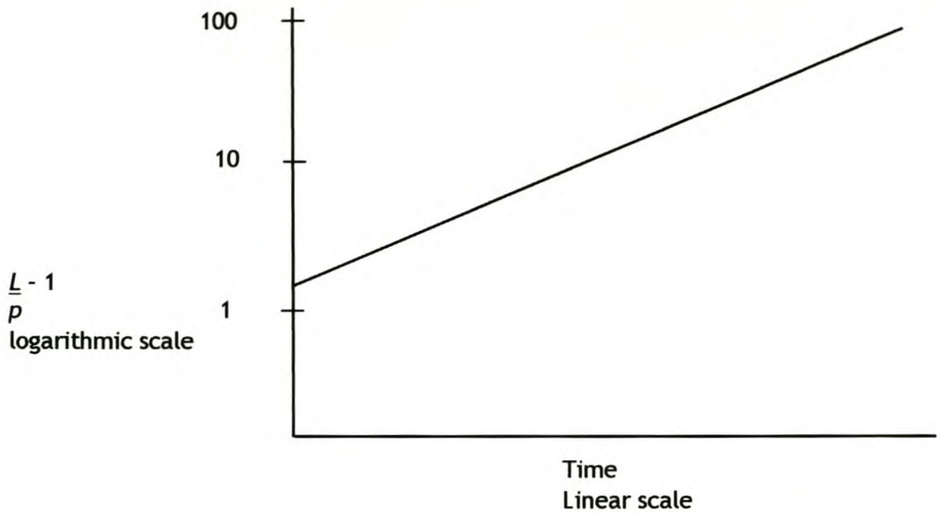


Figure 3.16: Technological progress on log-linear scale

There are a number of advantages to be obtained by transforming the data so that they can be plotted as a straight line. For example, it is possible to define a best-fit line using a simple linear regression where the formula for the line is:

$$y = A + Bx$$

and the constants A and B are defined as:

$$A = \frac{\sum y}{n} - \frac{\sum Bx}{n}$$

$$B = \frac{\sum xy - \sum x \sum y / n}{\sum x^2 - \left(\sum x\right)^2 / n}$$

One great advantage of transforming the curve to a straight line is that the human eye finds it easier to interpret. If a point diverges from a straight line it is much more obvious than a similar divergence from an S-curve. This alerts the forecaster and prompts him to investigate it further. This may reveal that the data relating to that point may be suspect; in this case he may decide that it is sensible to ignore it and re-compute the line. Alternatively, he or she may find that there is a cause for the divergence, which adds to his knowledge of the influences affecting the progress of technology.

If the line, which is plotted in linear form, exhibits a dogleg coinciding with the end of the factual data, then one must assume that the forecast is erroneous, unless a reason can be found for why the present marks a point of discontinuity.

A technology substitution is likely to occur as the current technology approaches its natural limit. When the new technology is considered, it is usually not yet proven and could have lower performance levels than the existing technology. This is shown by time "t" in Figure 3.17.

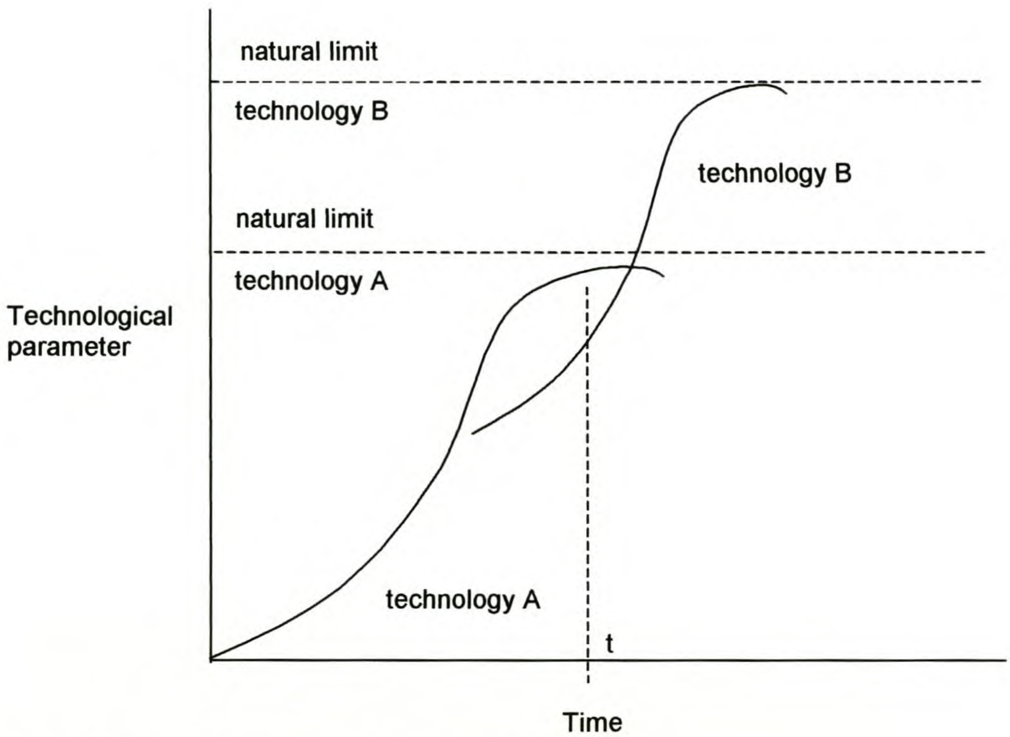
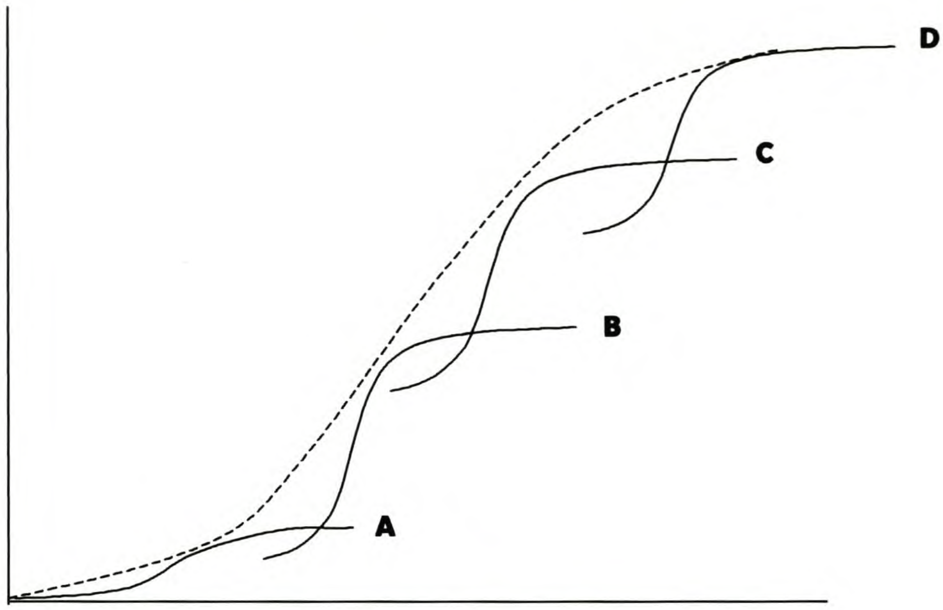


Figure 3.17: Technology substitution (Twiss, 1992)

Consideration of the S-curves and their natural limits focuses attention on the future and dynamics of the substitution process. This is a powerful tool for the forecaster in assessing when a major technological change may be introduced. It remains important for the forecaster to take a wide-ranging view of the whole field of technology, since the significant developments may be taking place in an area outside his immediate concerns.

When a series of substituting S-curves for a technological parameter is plotted, it is often found that they can be contained within an envelope curve, which is also of an S-shape. This is illustrated in Figure 3.18.



A, B, C, D are successive technologies

Figure 3.18: The envelope curve (Twiss, 1992)

There are three possible outcomes of how a new product will affect the total market:

- One-for-one substitution, where the total size of the market is not affected by the substitution. Where this occurs, the product substitution technique can be used without modification.
- Market segmentation, where the new product affects a proportion of a market. Before conducting a substitution forecast, it is necessary to establish whether the market will segment and assess the sizes of the two segments. The substitution forecast is then only conducted on the relevant segment affected by the new product.
- New Markets are established because the performance of the products has greater value and/or lower price than the previous product. This cannot be regarded as substitution. An example is the replacement of the slide rule with the calculator (Twiss, 1992).

The S-curve has a wide application in establishing the trends for the various machines making up the Forest Engineering value chain, provided that sufficient past data points are available for the number of machines that has been sold in the particular region included in the forecast.

c) The Fisher-Pry technique

The dynamics of product substitution were first established by Fisher and Pry whose names are attached to the most widely used technique. By examining a large number of past substitutions, they showed that the fraction of the total market (f) increased with time along the familiar logistic or S-curve. Similarly, the decay in the fraction represented by the old product (1-f) described a reversed S-curve (Figure 3.19a).

The analysis of the historical data led them to two conclusions which provide the basis for the forecasting technique. These are:

- When f reached 5% there was a high probability that the substitution would proceed to completion. It is still possible to use lower percentages in the forecasting process but the confidence would be reduced.
- The data for the first 5% is sufficiently accurate to enable the shape of the S-curve to be established and for it to be used as a basis for forecasting the future progress of the substitution. This assumes that no new factors emerge which affect the underlying dynamics of the process.

The substitution relationship can be expressed algebraically as:

$$f = \frac{1[1 + \tanh a(t - t_0)]}{2} \qquad \text{OR} \qquad f = \frac{\exp 2a(t - t_0)}{1 - f}$$

where f = fraction substituted

a = half the annual fractional growth in the early years

t_0 = time when f equals a half

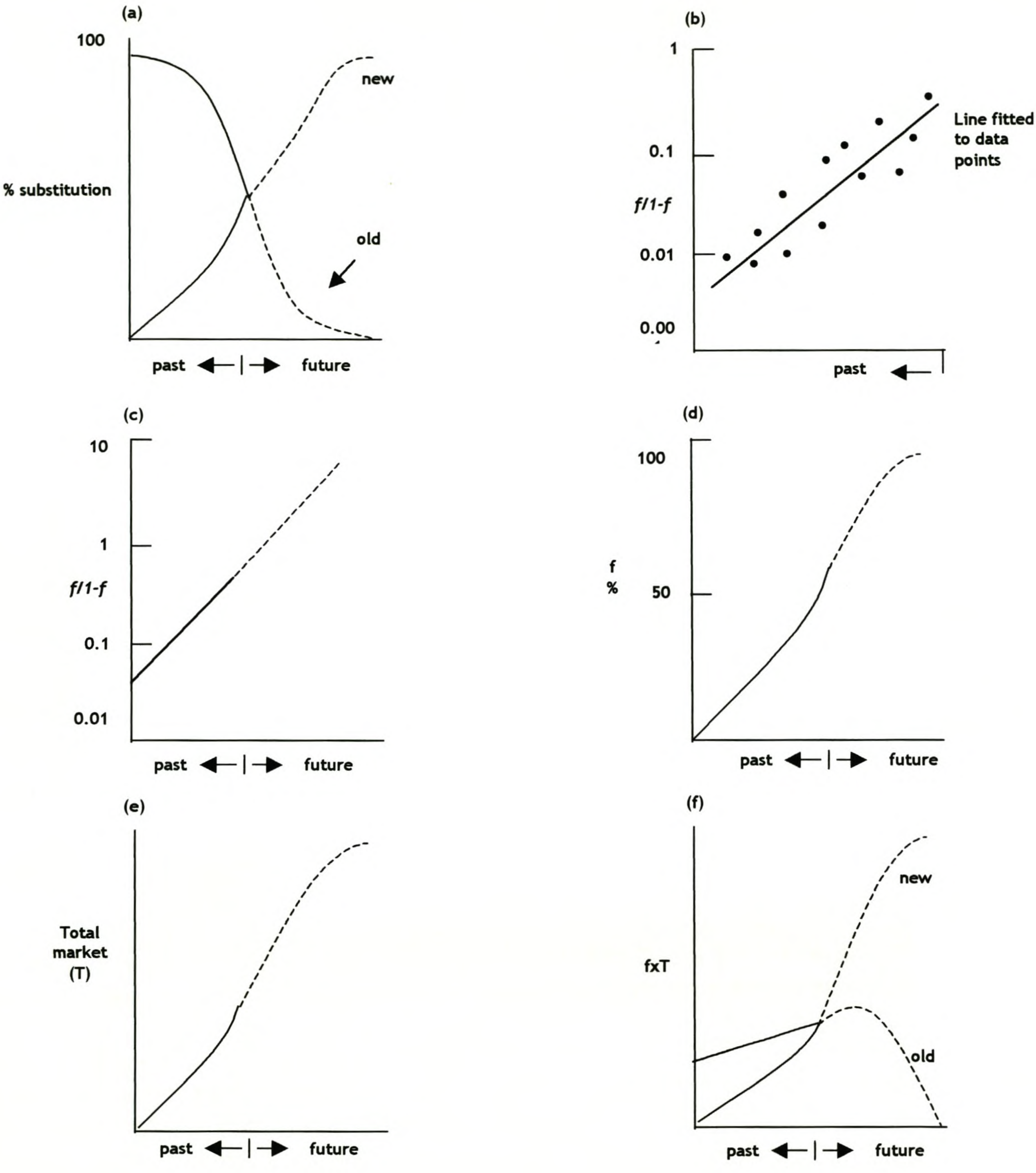


Figure 3.19: Product substitution analysis – The Fisher-Pry technique (Twiss, 1992)

The recommended procedure is to obtain a forecast using the available data and then to examine what other factors might modify it. The steps to be undertaken in making the forecast are described below:

Step 1

Collect data for the existing and the substituting products. Calculate *'f' and '1-f'*.

Step 2

Plot *f/(1-f)*. Fit a straight line (Figure 3.19b). The fitting of a best fit curve by regression analysis is regarded as appropriate. The forecaster must now decide which is the most appropriate straight line to fit to the data points. He will normally have two choices:

- To fit a best-fit line to all the data points, perhaps ignoring any which appear to be rogue; or
- To fit a line to the most recent data points if they appear to have a different slope from those for the earliest data; it is assumed that these later points are more representative of the long-term trend.

This choice is difficult to resolve. However, it must not be forgotten that the purpose of making the forecast is to aid decision-making. If two different judgments in fitting the line would lead to different decisions, the forecast is of little practical value. In the real world, no one is going to base an important decision on a fine distinction in the fitting of a line to data points on a graph. However, if the decision is the same in both cases it is irrelevant to the decision which line is used. Thus, the recommended procedure is to fit one line, carry out the forecast to its conclusion and then check that a different decision would not have been made if the other line had been used. Once a straight line has been fitted, it will be used for the subsequent steps and the data points will not be used further.

Step 3

Re-plot the straight line from Step 2. This enables the straight line to be extrapolated to give forecast values for *f/(1-f)* (Figure 3.19c).

Step 4

The next stage in the analysis is to derive values for *f* at dates in the future. This can be calculated by taking a series of readings for *f/(l —f)* in lie future and carrying out the following computation.

Let the value of f/(1-f) at time 't' be the *'y'*

Then $(f/1-f) = y$

$f=y(1-f) = y - yf$

$f+ yf= y$

$f(1+y) = y$

$f=y/(1+y)$

Thus, when $y= 1$, $f = 1/(1+1) = 0.5$

$y = 10$, $f = 10/(1+10) = 0.91$

The fact that readings of $f/(1-f)$ above 10 cannot be obtained, is not important since it would be unrealistic to expect to obtain an accurate forecast for the final 9% of the substitution from data relating to the first 5%. By plotting the values of '*f*' obtained in this way on linear graph paper the S-curve is derived (Figure 3.19d).

Step 5

The growth of the size of the total market must now be forecast. This can usually be obtained from a simple extrapolation of past data (Figure 3.19e). The forecast value for '*f*' at dates in the future can now be multiplied by the corresponding size of the total market $(f \times T)$ to obtain the size of the market for the new product (Figure 3.19f). It should be noted that this gives the cumulative market. Annual increments must be calculated to obtain the size of the annual market, which is usually the most important consideration for the decision maker.

Step 6

The plotting of the curves to this stage has been mechanistic and as such other factors known or considered possible to the forecaster have been ignored.

The Fisher-Pry substitution technique is one of the most valuable tools available to the forecaster but it is not used to the extent that it should be. Because of its origins within technology forecasting, few forecasters in the marketing function appear to be aware of it. Although it has been described within the context of forecasting, it can be seen that it reveals a large number of insights into the dynamics of the market, which are a reflection of consumer behaviour.

Where the forces driving the substitutions relate solely to the relative technological performance of the two products, the straight line forecast obtained in Step 3 has a high probability of describing the future rate of substitution without serious error (Twiss, 1992).

The Fisher-Pry technique can be used to determine the substitution of one system type in the Forest Engineering value chain, with another. For example, it would be important to establish what the future market share will be of machines in cut-to-length systems, as opposed to those used in tree length systems.

d) Expert judgment

In the absence of formal forecasting methods, future orientated decisions must be based solely on judgment. Sometimes an individual working alone will make the best judgment, whilst a forecast using a formal method might be far off the mark. Generally though, it is advisable to draw on the expertise of a team of people due to the complexity of many technological product and process decisions.

The impact of non-technological factors such as political, economic, social and environmental requires that experts be selected who understand the environment in its full sense.

The quality of a judgmental forecast is highly dependent upon the knowledge of the experts consulted. Ideally, world authorities in their specific fields should be used. This complicates the ability to convene a meeting where the required experts are all present due to the logistics involved.

Other problems, which could occur during the process at a meeting, are:

- differences in the authority of attendees;
- differences in persuasiveness;
- reluctance to admit errors; and
- desire to conform.

The forecaster commonly uses expert judgment, specifically when making assumptions. This will also be necessary to forecast the Forest Engineering value chain, as the forecaster will require to construct various possible value chains, which could be used in the future and which will then be evaluated in order to establish the most appropriate system or systems for the future.

e) The Delphi technique

A method, developed specifically to overcome the shortcomings of face-to-face meetings is the Delphi technique (Twiss, 1992). Delphi is a widely used method for achieving a structured anonymous interaction between carefully selected experts by means of a questionnaire, with controlled feedback. This technique is often used for a technological forecast (Adam and Ebert 1978). The Delphi is of most valuable in making long-term forecasts (Twiss, 1992).

The objectives of the type of forecast where Delphi is used are one of the following:

- to set normative targets;
- to identify new factors influencing the future state of technological developments or new needs which might be satisfied;
- to determine the commencement and shape of the S-curve of a new technology; and
- to establish the feasibility of a development under stated conditions.

The stages of the Delphi are:

- Appointment of an administrator, who is usually also the forecaster himself.
- Preparation of a draft questionnaire.
- Selection of experts.
- Validation of the questionnaire.
- Circulation of the questionnaire to the experts (Round 1).
- Analysis of Round 1 results and return to experts (Round 2).
- Analysis of Round 2 and return to experts (Round 3).
- Analysis of Round 3 results and preparation of the final forecast.

(Adam and Ebert, 1978).

The number of experts to be involved is dependant upon the nature of the problems being investigated. The administrative burden of selecting the right experts must not be under-estimated. The quality is much more important than the number. It is far better to have a small focused study involving high calibre participants than a large effort of poor quality. For most Delphi's 15 to 40 participants is normal, with 25 being the most desirable. It does not necessarily purport an accurate prediction of the future, but rather gives guidance in the development (Twiss, 1992).

Due to the nature of the Delphi technique, which disallows interaction between respondents, the following should be taken into consideration when interpreting results:

- A wide divergence of responses on a particular question reflects either:
  - an uncertain future, as the panel cannot agree; or
  - an improperly phrased question to which the panel can only guess; or
  - widely divergent requirements of respondents.
- A narrow deviation from the mean (little divergence) illustrates either:
  - a clear consensus and thus a relatively certain future; or
  - a rhetorical question which only allows for one kind of answer; or
  - a consistent (mis) interpretation of the question

(Drake, Beam & Morin, 1996).

Because of the importance of the divergence on the results, it is necessary to carefully analyse the results by using a technique, which would best describe the divergence. Such a technique is the Box and Whisker Plot. Montgomery, Runger and Hubele (1998) describes the Box Plot is a graphical display that simultaneously describes several important features of a data set, such as centre, spread, departure from symmetry, and identification of observations that lie unusually far from the bulk of the data. These observations are called "outliers". A Box Plot displays the three quartiles, on a rectangular box, aligned either horizontally or vertically (refer to Figure 3.20). The box encloses the interquartile range with the left (or lower) edge at the first quartile, $q1$, and the right (or upper) edge at the third quartile, $q3$. A line is drawn through the box at the second quartile (which is the 50th percentile or the median), $q2 = x$. A line, or whisker, extends from each end of the box. The lower whisker is a line from the first quartile to the smallest data point within 1.5 interquartile ranges from the first quartile. The upper whisker is a line from the third quartile to the largest data point within 1.5 interquartile ranges from the third quartile. Data farther from the box than the whiskers are plotted as individual points. A point beyond a whisker, but less than three interquartile ranges from the box edge is called an outlier. A point more than 3 interquartile ranges from a box edge is called an extreme outlier. Occasionally, different symbols, such as open and tilled circles, are used to identify the two types of outliers.

Figure 3.20 represents a box plot for alloy compressive strength data. This box indicates that the distribution of compressive strengths is symmetric around the central value, because the left and right whiskers and the lengths of the left and right boxes around the median are about the same. There are also two outliers on either end of the data. Box plots are very useful in graphical comparisons among data sets, because they have high visual impact and are easy to understand.

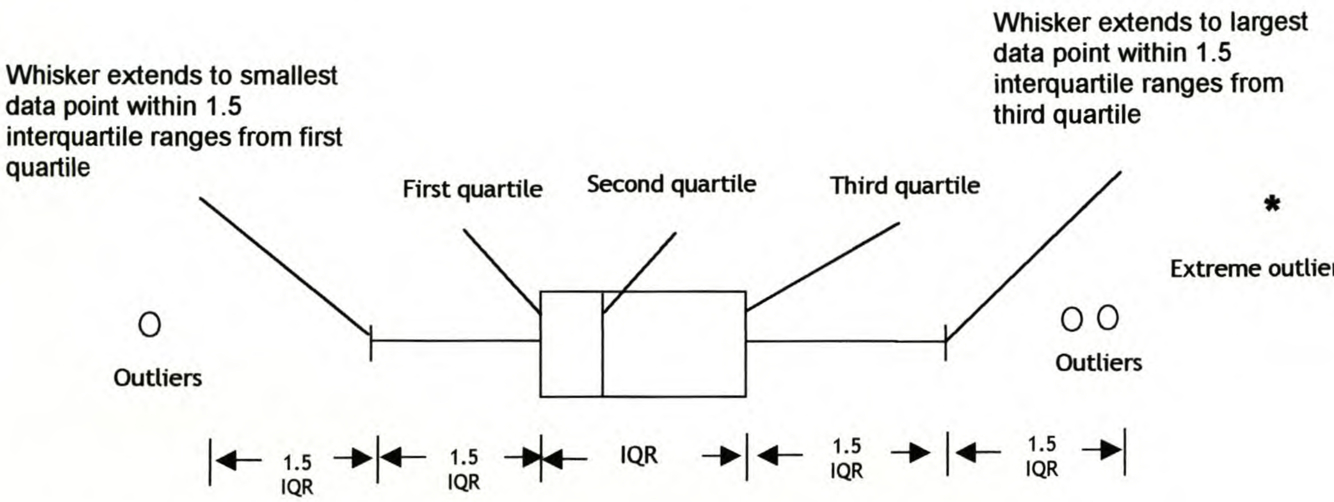


Figure 3.20: Description of a box plot (Montgomery, et al., 1998)

The description of the Box Plot is substantiated by SAS Procedures Guide (1995), who describes it as a schematic plot, where the bottom and top edges of the box are located at the sample 25^{th} and 75^{th} percentiles. The centre horizontal line is drawn at the sample median and the central plus sign (+) is at the sample mean. It is possible for all of these statistics to fall on the same printer line. The central vertical lines, called *whiskers*, extend from the box as far as the data extend, to a distance of, at most, 1.5 interquartile ranges (an interquartile range is the distance between the 25^{th} and 75^{th} sample percentiles). Any value more extreme than this is marked with a zero if it is within three interquartile ranges of the box, or with an asterisk (*) if it is still more extreme. The third plot, a normal probability plot, is a quantile-quantile plot of the data. The empirical quantiles are plotted against the quantiles of a standard normal distribution. Asterisks (*) mark the data values. The plus signs (+) provide a reference straight line that is drawn using the sample mean and standard deviation. If the data are from a normal distribution, the asterisks tend to fall along the reference line. The vertical co-ordinate is the data value, and the horizontal co-ordinate is:

$$\phi^{-1}((r_i - 3/8) / (n+1/4))$$

where

r_i = is the rank of the data value

ϕ^{-1} = is the inverse of the standard normal distribution function

n = is the number of non-missing data values

(SAS Procedures Guide, 1995).

The Delphi technique is the ideal tool to identify the future change drivers that will impact on the Forest Engineering value chain. These forecasts are generally of a long-term nature, which is well suited to the Delphi technique. This technique is significantly more objective than expert judgment.

f) Cross-impact analysis

The term cross-impact analysis is applied to those techniques, which aid the understanding of developments in one area that affects those in another. The value of this is twofold:

- To identify the most important inter-relationships between variables.
- To provide a structure for a more detailed forecasting exercise. It identifies those issues and inter-relationships that should be examined in detail. (Twiss, 1992).

A matrix is used to conduct the cross-impact analysis as this is a very effective tool to show the presence or absence of relationships between pairs of elements (Quest, 1995).

Firstly, a prepared list of issues is prepared. The cross-impacts are then assessed through the allocation of the intensity and the direction of the impact.

- Intensity: High, medium, low or zero.
- Direction: Positive or negative.

The matrix shown in Figure 3.21 is a simplified version, after Twiss (1992), to illustrate the methodology. Each issue is listed on both the longitudinal and vertical axes. It is important that the individual or group conducting the analysis, in order to prevent any ambiguity, which might otherwise appear at a later stage, understands the full meaning of each description.

The procedure is to work horizontally across the matrix by asking a series of questions e.g.:

> "If the size of the workforce decreases, what will be the affect on the cost of labour?"
>
> The H+ indicates that it will have a high positive impact.
>
> If there is no direct causality, the "0" is used, such as in box 1:4.
>
> It should also be noted that there are two cross-impacts between each pair of variables, which need not be identical.

	Decrease in workforce ❶	Cost of labour ❷	Capital investment ❸	Robotic technology ❹
Decrease in workforce ❶		H^+	M^+	0
Cost of labour ❷	L^+		M^+	H^+
Capital investment ❸	L^+	L^+		H^+
Robotic technology ❹	M^+	L^+	H^+	

Figure 3.21 Example of a cross-impact matrix (Twiss, 1992)

It is usually acceptable to focus only on the high cross-impacts.
The important issues and relationships identified in the matrix are analysed in more detail. The trends fall into one of five categories:

- Those where hard data is available.
- Those where well established trends exist and forecasts are available from published sources.
- Those where forecasts do not exist, but where the data can be found and the forecast can be made.
- Weak signals which could develop into significant trends.
- Events, which may or may not happen.

The cross-impact matrix can be combined with other forecasting techniques, such as the Delphi, to assist the forecaster in identifying the key cross-impacts that need to be considered in the forecast. This is very relevant in isolating the high cross-impact change drivers for the Forest Engineering value chain. The matrix thus forms the foundation for future work, where forecasts are made using a wide range of techniques. When this has been completed, the results need to be accumulated to create an overall forecast. This is the most difficult part of the forecast, as the individual forecasts and their aspects have to be aggregated into a coherent picture of their combined implications.

g) Pareto analysis

This analysis is used to record and analyse data relating to a problem in such a way as to highlight the most significant areas, inputs or issues. Pareto analysis often reveals that a small number of failures are responsible for the bulk of quality costs, a phenomenon called the Pareto Principle. This pattern is also called the "80/20" rule and manifests itself in many ways. For example:

- eighty percent of sales are generated by 20% of customers.
- eighty percent of quality costs are caused by 20% of the problems.
- Twenty percent of stock lines will account for 80% of the value of the stock.

A Pareto diagram allows data to be displayed as a bar chart and enables the main contributors to a problem to be highlighted (Quest, 1995). The steps involved in using the Pareto analysis are as follows:

- Gather facts about the problem, using check sheets or brainstorming, depending on the availability of information. For example; typing re-work, as shown in Table 3.3.

Table 3.3: Typing rework analysis using Pareto analysis (Quest, 1995)

Reasons for typing re-work	No of times
Author errors	12
Incorrect entry	2
Poor layout	5
Improved content	15
Information became out of date	3

➢ Rank the contributions to the problem in order of frequency (Table 3.4).

Table 3.4: Ranking of typing errors (Quest, 1995)

Reasons for typing re-work	**No. of times**
Improved content	15
Authors' errors	12
Poor layout	5
Information became out of date	3
Incorrect entry	2
Total	**37**

➢ Draw the value (errors, facts etc.) as a bar chart, as shown in Figure 3.22.

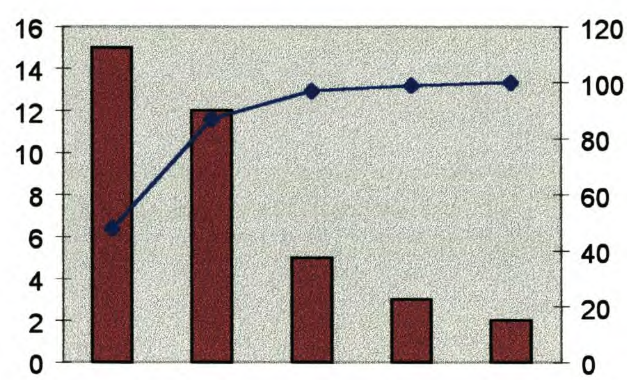


Figure 3.22: Results of a Pareto analysis (Quest, 1995)

➢ Review the chart – if an 80/20 combination is not obvious, you may need to re-define your classifications and go back to Stage one or two.

Pareto analysis is a useful tool to:

➢ identify and prioritise major problem areas;
➢ separate the "initial few" from the "useful many" things to do; and
➢ identify major causes and effects.

The technique is often used in conjunction with brainstorming and cause and effect analysis, but does not show significant potential in assisting in the forecasting of the

Forest Engineering value chain. The cross-impact matrix is a much more powerful tool that can be used instead.

h) Benchmarking

Benchmarking is not a forecasting technique *per se*, but is a useful tool to assist with planning for future strategy. It is therefore useful to discuss the principles of benchmarking in this Chapter.

Benchmarking is the process of learning from others as a basis for setting stretch goals, identifying breakthrough processes and accelerating improvement towards world-class performance standards (Quest, 1995). A major focus in determining a firm's resources and competencies is comparison with competitors. Firms in the same industry often have different marketing skills, financial resources, operating facilities and locations, technical expertise, levels of integration and management skills. Benchmarking has become a central concern of managers in quality commitment companies worldwide. Particularly as the value chain framework has taken hold in structuring internal analysis, managers seek to systematically benchmark the costs and results of the smallest value activities against relevant competitors or other useful standards, because it has proven to be an effective way to continuously improve that activity. The ultimate objective in benchmarking is to identify the "best practices" in performing an activity, to learn how to lower costs, have fewer defects, and thereby improve performance. Companies committed to benchmarking attempt to isolate and identify where their costs or outcomes are out of line with what the best practices of a particular activity or experience are and then attempt to change their activities to achieve the new best practices standard. Comparison with key competitors can prove useful in ascertaining whether their internal capabilities on these and other factors are strengths or weaknesses (Pierce and Robinson, 2000). Some examples of benchmarking used by firms in the past are:

- An insurance company benchmarked an electricity utility in order to improve their direct debit order process.
- Motorola benchmarked Domino Pizza to improve local deliveries.
- A manufacturer benchmarked Formula 1 pit teams to improve tool changeover times.

Benchmarking is used to systematically identify stretch goals for being world-class, to identify ways of achieving improved performance and to help an organisation to learn from others (Quest, 1995).

Benchmarking follows a simple, seven-step process (Figure 3.23):

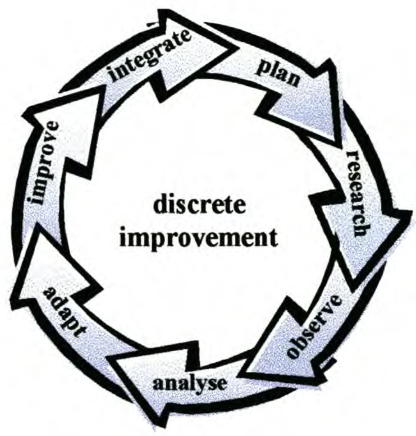


Figure 3.23: The seven-step benchmarking process (Quest, 1995)

Plan : Decide what to benchmark, when to do it, whom to involve and what other resource will be required.
Research : Internally identify existing performance standards and processes. Externally identify whom to benchmark against and collect as much data as possible, e.g. from trade press, libraries, contacts, and product literature. Don't forget you may be able to benchmark against other companies/divisions in your group.
Observe : Where possible, visit to observe and test the data collected.
Analyse : Dig into the data and observations to identify, for example, learning points and new approaches. Compare with your own existing performance. Set stretch goals using what you have learnt.
Adapt : Adapt the process, techniques, tools etc. that you have gathered to fit your circumstances and to meet your goals.
Improve : Identify ways in which the new process/product can be further improved or enhanced so that you exceed, rather than equal the benchmark.

Integrate : Implement the new process/product rigorously and ensure alignment with other processes and activities. Amend schedules/jobs/layouts etc. to ensure that the new way is fully integrated into the business.

Benchmarking the costs of various Forest Engineering value chains is only recommended when the forecaster is unsure of how to configure alternative value chains that need to be evaluated. The alternatives form the basis of selecting the appropriate value chain, but can alternatively be configured by using expert judgment.

i) *Brainstorming*

Brainstorming is a technique that encourages creative thinking and the generation of ideas. Analysis and evaluation are prevented in the early stages of brainstorming, ensuring radical and different ideas are aired.

The suggested steps in brainstorming, as proposed by Quest (1995) are as follows:

- Assemble the brainstorming group.
- Appoint a scribe, and if appropriate, a separate timekeeper.
- Explain the purpose of the meeting and the ground rules. Agree a statement on the topic or issue to be brainstormed. Write this up at the top of the chart.
- Allocate time to brainstorm and time to review the outputs; 5-20 minutes is usually sufficient for generating ideas, but brainstorms can go on for hours. The ground rules for brainstorming are given in Table 3.5.
- Start the ideas coming - make sure that all ideas are visible to everyone in the group.
- Either allow random contributions or go around the team repeatedly to ensure everyone is involved. Individuals can "pass" if they have nothing to add.
- As scribe, don't abbreviate or interpret. It is important to capture ideas exactly as expressed.
- Having generated a number of ideas, you can then evaluate their usefulness towards meeting the original objective. At this stage, analytical thought should be used. Before doing this, you may need to seek clarification as not all suggestions may be clear to everyone. Also, check for duplications and amalgamate, if appropriate.

- Establish some initial classification. Group ideas with a common theme for example.
- Evaluate and select the most appropriate ideas. It is here that the output from the brainstorming session can become the input for other techniques/tools such as cause and effect analysis, paired comparisons, consensus reaching.

Table 3.5: Rules for brainstorming (Quest, 1995)

Rule	Explanation
o No criticism	o Crucial if barriers to creative thinking are to be overcome
o Encourage wild ideas	o All ideas are acceptable
o Strive for creativity	o Generate as many ideas and volume as possible
o Hitch-hike	o Build on, add to and combine ideas
o List all ideas	o No editing or interpretation by the scribe
o Incubate	o Taking time to reflect on ideas Listening often stimulates new thoughts

For example Table 3.6 below indicates the various ways a baked bean tin can be used if such a question is posed in a brainstorming session.

Table 3.6: Uses of a baked bean tin

Uses of a baked bean tin	
Plant pot	Cooking pot
Pencil holder	Mouse's bed
½ a telephone	Measuring tool
Storage	Roller
Leg for broken table	Drinking cup
Rubbish disposal	Bracelet
Prickly pear picker	

Brainstorming provides a disciplined (but fun) way to involve people in generating new ideas, so challenging previous assumptions and paradigms. It is a creative technique, which should be used in most forecasts. This is an alternative method for assisting the forecaster in selecting alternative value chains, identifying high cross-impacts between change drivers and scanning the environment.

j) Scenario building

In an unstable world, there are many unknowns, which are not possible to forecast however sophisticated the technique used. Twiss (1992) uses the example of the oil price to illustrate this. Any detailed analysis of world supply and demand is unlikely to give an accurate forecast of the price ten years ahead because of uncertainties in supply, for example, political developments in the Middle East, and in demand, due to possible regulations to limit carbon dioxide emissions. One might conclude that a price of 20 dollars a barrel is as likely as 40 dollars. In this case, it is possible to derive two different views of the future, or scenarios, one based on a price of 20 dollars a barrel and the other on 40 dollars.

A scenario accepts that the future is not deterministic and that alternative views of it are feasible. Its purpose is not to predict the future but rather to grasp how uncertainty about different forces can lead to very different futures. A scenarios process helps to identify these forces and their interaction, as well as to recognise significant changes, as they unfold. The value of scenario planning lies in its ability to envisage a multiplicity of futures without selecting any particular one, precisely because the future is uncertain. This flexibility improves our ability to respond to future events without being locked into a narrow perspective, particularly one that simply extrapolates the present into the future. Scenarios thus depict plausible future worlds dependent on the extent to which identified key uncertainties unfold (Environmentek, 2001). This approach has been adopted by an increasing number of companies in recent years. There is a greater need for decision making systems that can respond, learn and adapt quickly and effectively than there is for one that, using the predict-and-prepare paradigm, produces so called "optimal" solutions that either deteriorate rapidly with changing conditions or are stillborn (Buys, 2000).

The following factors describe the characteristics of scenarios:

- Scenario-based forecasts are highly descriptive, alternative views of the future that vary along key dimensions. The intent is to gain insight into possible events that might not otherwise be considered.
- They depict possible futures and their implications.
- They do not state what should be done – that is the domain of the decision maker.
- They are hypothetical sequences of events constructed for the purpose of focusing attention on causal processes and decision points.
- In these rapid changing times, scenarios are a viable way to format high-change environments for strategic decision- making (Buys, 2000).

Buys (2000) describes the various types of scenario approaches, as shown in Figure 3.24.

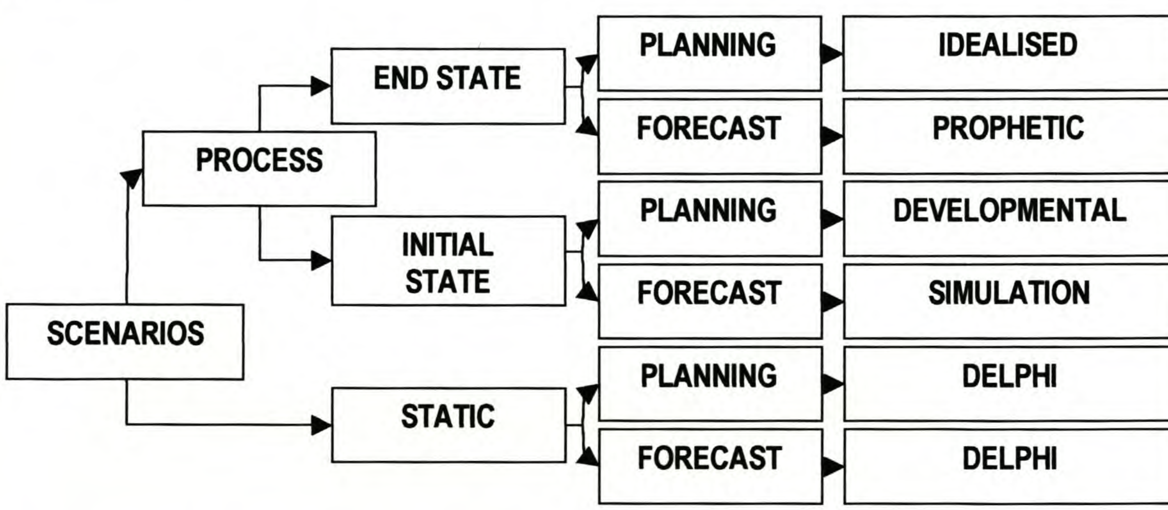


Figure 3.24: Classification of scenarios (Buys, 2000)

Scenarios are either process orientated or static in their approach. Process scenarios consider an end state and forecast backwards, or use the current state as a point of departure and forecast into the future. Static scenarios can be of the planning or forecasting type, both for which the Delphi technique is recommended as an analytical tool.

Buys (2000) defined the steps for scenario building as follows:

- *Determine the focal issue.* This is usually determined by using interviews.
- *Identify key factors bearing on the focal issue.* Expert opinion is required for determining the key factors. In the case of static scenarios, the Delphi technique is recommended.
- *Identifying driving forces behind key factors.* The cross-impact analysis identifies the inter-relationship between the various driving forces and could be the basis for selecting the scenarios. Each scenario is based upon a different set of assumptions, but the issues addressed by these assumptions have been set to be inter-related. Thus, the cross-impact analysis assists in the selection of sets of consistent assumptions. For example, one might select a high oil price, low energy consumption per capita, and the development of energy efficient aero-engine technology, whereas a low oil price would not be consistent with either of the other two impacts. When a coherent set of assumptions has been agreed, it is then possible to examine how the detailed forecasts for the individual items interact, together with their organisational implications. This can then be repeated with another set of equally feasible consistent assumptions to give an alternative view of the future. In theory, there can be an unlimited number of scenarios selected for evaluation, although in practice their number is normally limited to two or three.
- *Classify driving forces.* After determining the cross-impacts of the various driving forces, these are divided into three groups:
    - Key certainties (apply to all scenarios)
    - Key controllables (plan and manage these)
    - Key uncertainties (alternative scenarios)

Spies (1986) classified the alternative futures as shown in Figure 3.25.

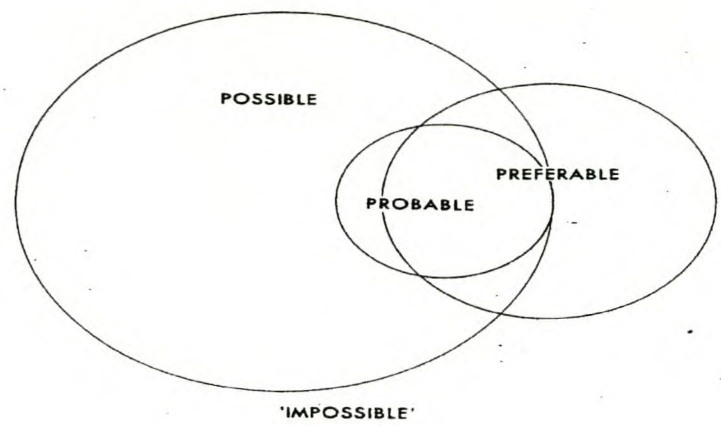


Figure 3.25: Alternative futures classified for scenario analysis (Spies, 1986)

The key certainties are those factors common to all possible futures. The cone of uncertainty is then narrowed down to only those factors that are uncertain in the future, as described by Huntley, Siegfried and Sunter (1989). Figure 3.26 shows the cone of uncertainty and the inner circle, reflecting the narrowing down of the cone, and created by removing certainties and controllables.

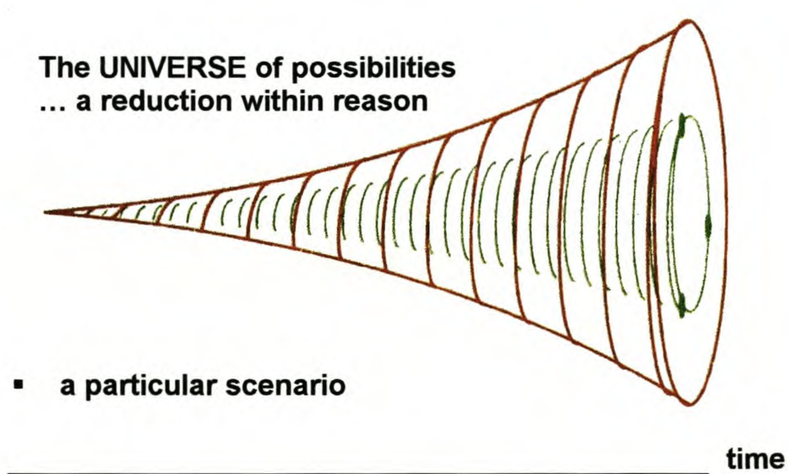


Figure 3.26: The cone of uncertainty (Huntley, Siegfried and Sunter, 1989)

- *Develop scenario logics.* There are differing views on how many stories to develop. Some companies are content with two, whilst others use three or four. Seed (1998) suggests that anything more than four is too many to absorb, and even with four, care must be taken that they are sufficiently different not to cause confusion. Many organisations use three scenarios, which consist of a median forecast, often referred to as "surprise free" and two others - one on either side of it (high growth or optimistic; low growth or pessimistic). There is, however, a danger in selecting three scenarios, in that management's attention is drawn to the central, or surprise free, scenario. It must be remembered that in the selection of the scenarios there was an assumption that they were all feasible, often equally so. Thus, they are all of equal importance. Some companies, therefore, recommended that only two scenarios representing the boundary conditions be presented so that attention is directed to the whole domain between them (Twiss, 1992).

➢ *Test scenario logics (comprehensive and plausible, yet extreme).* When the scenarios to be evaluated have been selected, the most time consuming part of the study can commence. This consists of detailed forecasting for each of the variables, other than for those whose values have been assumed in the scenario selection process. Each forecast will involve the normal tasks of data collection and the application of a formal forecasting methodology.

A major output from this will be a series of relationships for the alternative scenarios, which can often be represented graphically (Figure 3.27).

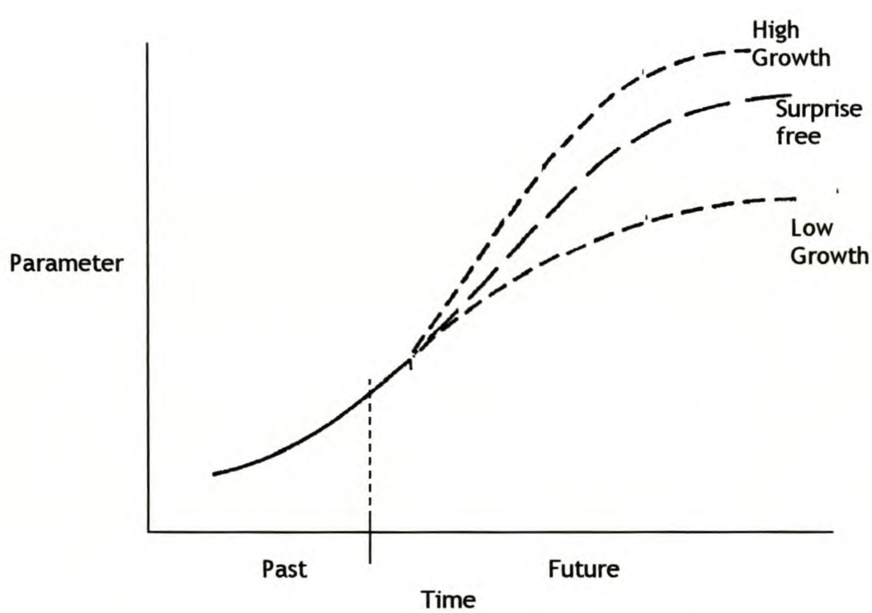


Figure 3.27: Representation of alternative scenarios (Twiss, 1992)

An alternative method of displaying scenarios is by using a matrix, as described in Figure 3.28:

	Environmental management	
Socio-economic trajectory	**STONG**	**WEAK**
HIGH ROAD	**RICH HERITAGE**	**BOOM AND BUST**
LOW ROAD	-	**SEPARATE IMPOVERISHMENT**
WASTELAND	-	**PARADISE LOST**

Figure 3.28: Scenario matrix for the South African environment (Huntley et al.*, 1989)*

Environmentek (2001) produced a similar matrix, to assist them in determining their research direction. They believe that it would add a longer-term dimension to the determination of strategic, technological and market needs and would develop a culture of strategic futures thinking within their organisation. They, based on global business network methodology, used a combination of scenarios generation and technology forecasting. Figure 3.29 illustrates their findings:

Figure 3.29: Scenario framework (Environmentek, 2001)

- *Write stories (scenarios).* The term "scenario writing" is used to describe this activity, since the output will take the form of a written report on the conclusions supported by the detailed forecasts. It is a "view" of the future in that it represents the collective views of the forecasting team after considering the totality of the information. This demands the exercise of considerable judgment and uses the data identified in the analysis of the change drivers.
- *Describe implications for focal issues.* This refers to identifying key indicators of which scenario(s) are developing, what will be the impact and what are the leverage points for the organisation.
- *Formulate strategies for dealing with scenarios.* The scenarios depict possible futures and their organisational implications, They do not state what should be done; that is the province of the decision maker and the planner who must now evaluate the desirability and relevance of alternative plans of action.

There are three possible outcomes for the strategies that have been prepared:

- A proposed strategy may be robust and appropriate to all scenario situations, making decision making simple.

- The current, or envisaged strategy, is unsatisfactory under all the scenarios. It then becomes necessary to devise a new strategy.
- The strategy is appropriate to one scenario but not another. In this situation there are several options:
  - To formulate a new strategy which is robust; or
  - To modify the current strategy, if possible; or
  - To prepare a contingency plan to enable a speedy response if future events show it to be necessary.
- *Optimise strategy for robustness.* It is important not to be drawn into thinking that one scenario is more likely than another is. Each story needs to be evaluated on its own merit. Seed (1998) suggests the following steps in drawing up a robust strategy:
  - How would this story affect my industry?
  - What would my company need to do?
  - Are my existing strategies appropriate for this world?
  - How will I prepare for the expected eventualities?
- *Monitor key indicators.* If they show that any of the scenarios are predominant, strategy can be shifted in that direction.

The success in forecasting with the aid of scenarios is reflected in their frequent use. Rapid change is also taking place within the systems used in the Forest Engineering value chain. This method is ideally suited to sketch alternative views of possible future value chains and managing towards the best alternative.

k) Environmental scanning

Environmental Scanning and scenario development are often used in tandem in strategy development. Spies (1986) refers to the combined role of environmental scanning and scenario development as being:

- to increase awareness and understanding of the process of change in the business environment that may affect the strategic position of an organisation;
- to improve the fit between an organisation and its current and future environment; and
- to enable an organisation to operate with maximum congruence and minimum friction in the changing conditions of an uncertain world.

He describes an organisation's environment as consisting of the social, political, institutional, technological, natural/physical and economic conditions within which it must operate. Environmental scanning therefore refers to the identification, evaluation and understanding of the past, present and possible future system in which one operates. Various models have been developed which can be used to conduct the environmental scanning exercise. One such model is that developed by Jacobs (1997). He distinguishes between 3 environmental entities, *viz*: the social environment, the task environment and the internal environment. This is described in more detail in Figure 3.30.

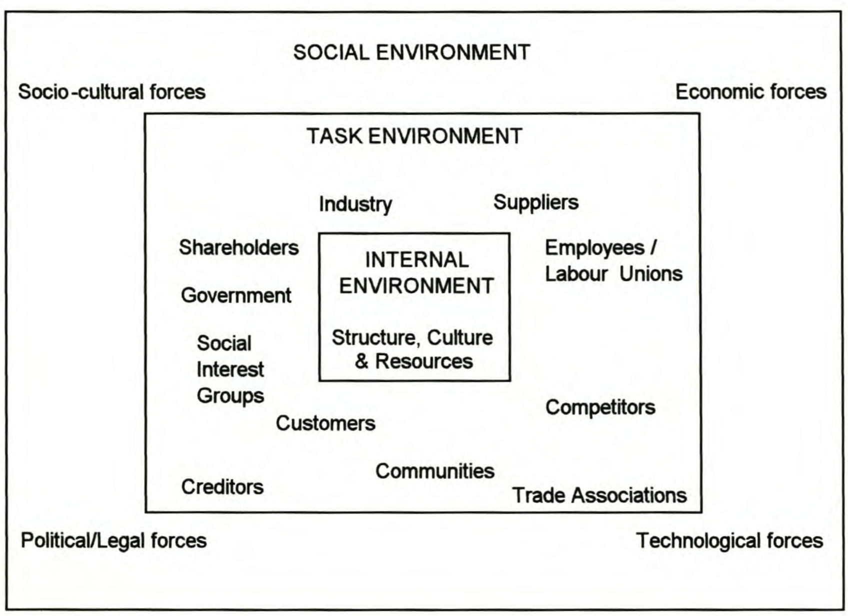


Figure 3.30: Strategic planning model (Jacobs, 1997)

Buys (2000) described the environment slightly differently, as shown in Figure 3.31, but in essence, the approach is similar.

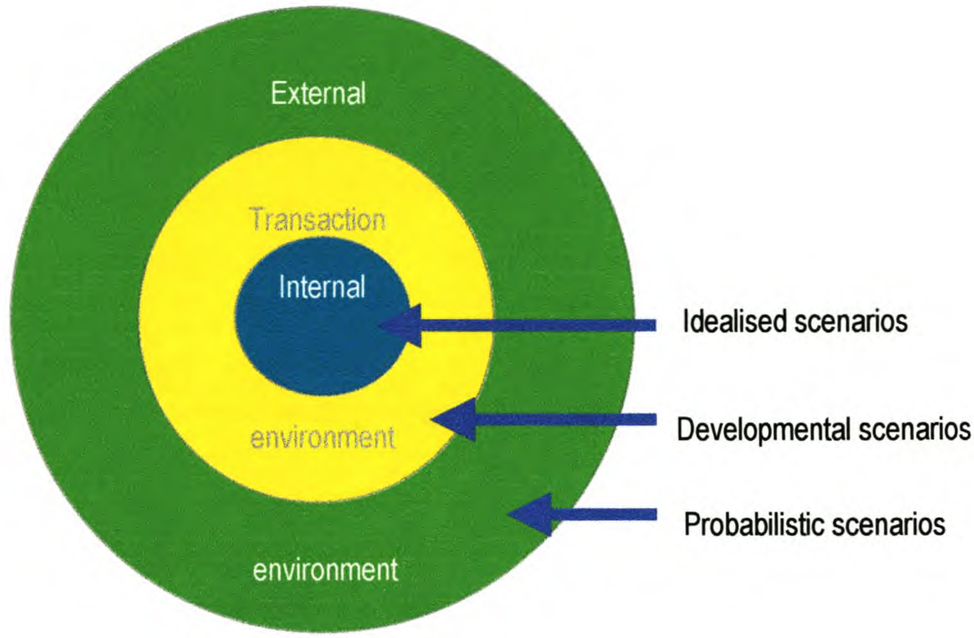


Figure 3.31: The strategic environment (Buys, 2000)

Buys, (2000) suggests that the environmental scanning planning model can be divided into two; one half applied to, for example, the global industry being analysed and then again repeated for the specific country, region or company being analysed.

The most common and established approach to an environmental scanning exercise is to use a SWOT analysis. A SWOT analysis is a graphical way of summarising a particular process, product, department or organisation, in terms of its strengths, weaknesses, opportunities and threats. (Quest, 1995). SWOT is an acronym for the internal **s**trengths and **w**eaknesses of a firm or industry and the environmental **o**pportunities and **t**hreats facing the particular firm or industry. SWOT analysis is useful for summarising all the various forces at play in a situation as a starting point for identifying areas for action (Quest, 1995). This technique has been a framework of choice among many managers for a long time because of its simplicity and its portrayal of the essence of sound strategy formulation. Central to making SWOT analysis effective is accurate internal analysis – the identification of specific strengths and weaknesses around which strategy can be built.

SWOT analysis can be used in many ways to aid strategic analysis. The most common way is to use it as a logical framework guiding systematic discussion of a firm's resources and the basic alternatives that emerge from this resource-based view. The following procedure is proposed by Pierce and Robinson, (2000) and Quest (1995) to conduct a SWOT analysis:

- Identify what is to be analysed (Figure 3.32).
- Brainstorm the four areas.

Strengths: Those internal characteristics behaviours/aspects of performance which are strong. A strength is a resource advantage relative to competitors and to the needs of the markets a firm or industry serves or expects to serve. It is a distinctive competence when it gives the firm a comparative advantage in the market place. Strengths arise from the resources and competencies available to the firm.
Weaknesses: Those internal characteristics behaviours/aspects of performance which are weak. A weakness is a limitation or deficiency in one or more resources or competencies relative to competitors that impacts a firm's effective performance.
Opportunities: Events, openings or changes external to the body being analysed which give positive opportunities for growth or improvement. An opportunity is a major favourable situation in a firm's environment. Key trends are one source of opportunities. Identification of a previously overlooked market segment, changes in competitive or regulatory circumstances, technological changes and improved buyer or suppler relationships could represent opportunities for a firm or industry.
Threats: Events or changes external to the body being analysed, which could be detrimental to performance. A threat is a major unfavourable situation in a firm's environment. Threats are key impediments to a firm's current or desired position.

- List each in the appropriate quadrant of a diagram, as illustrated in Figure 3.32.
- By discussion or voting, identify the relative strengths or importance of the factors listed in order to agree priorities for action.

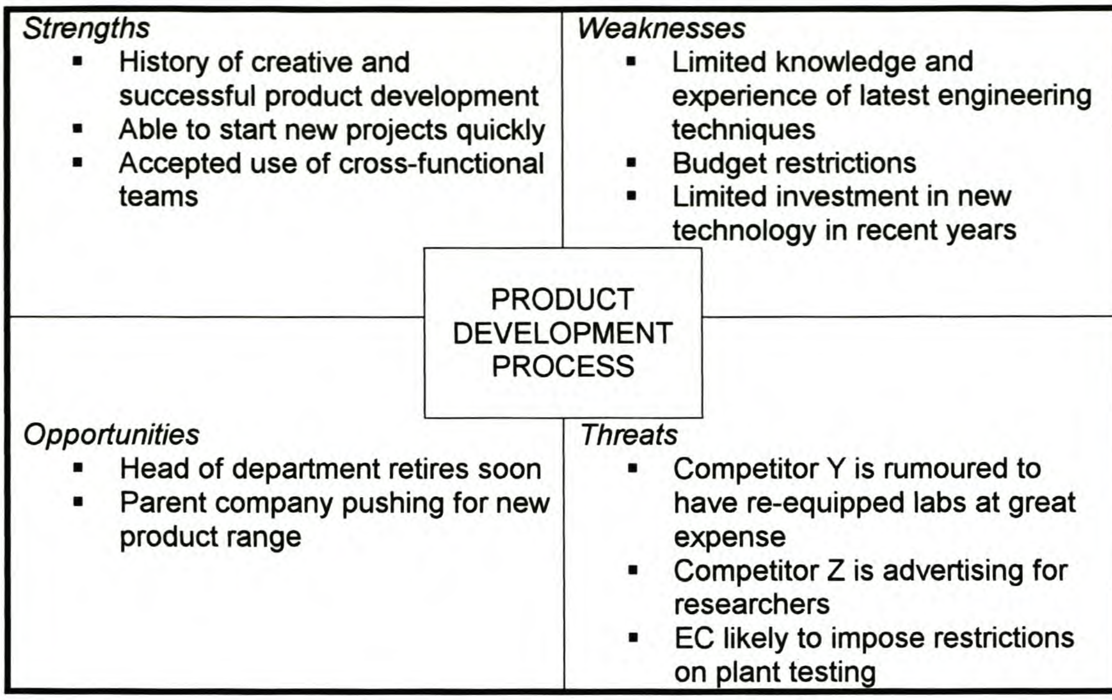


Figure 3.32: An example of a SWOT diagram (Quest, 1995)

Without an understanding of the wider environment within which the Forest Engineering value chain operates, the forecast will be incomplete. Considering that this technique is commonly used in conjunction with other techniques, it should be included in the overall forecasting method of the Forest Engineering value chain.

3.4 Financial evaluation methods

Part of the exercise of developing an appropriate forecasting method involves the selection of a sound method to compare the alternative systems making up the Forest Engineering value chain with each other. Alternative financial evaluation methods are investigated and recommendations made with regard to their relevance in the forecasting methodology.

3.4.1 Discounted Cash Flow method

Methods that take the "time value of money" into account by calculating the present values of the cash flows in the different periods are classified as discounted cash flow methods. Generally, this means that the cash flows of the different projects are discounted to present values.

The methods which fall into this classification, are the Net Present Value (NPV), Internal Rate of Return (IRR), and the Profitability Index (PI) methods. Both the IRR and PI are based on the NPV. The NPV and IRR methods are discussed in more detail below.

3.4.1.1 The Net Present Value method (NPV)

This method forms the basis of discounting techniques and its elements are needed as inputs in the application of the other two techniques (Internal Rate of Return and Profitability Index).

The basic inputs which are required are the following: -

- *Future residual values.* The residual value that will be realised at the end of a project is added to the cash flow of that particular year. Mistakes in the forecasting of the residual value are usually not critical, as the PV's of these values are normally relatively small.
- *Current realisable values.* For the purpose of the discounted cash flow (DCF) analysis, investments in machinery, equipment, and supplies are viewed as cash flow in year 0 of the project. All investments are thus treated equally in year 0. During the last year of the project there can, however, be a difference, as some investments may have a residual value (e.g. vehicles) while others may be literally exhausted (e.g. machinery). When an existing asset is to be sold, the simplest approach is to subtract its sale as scrap value (the realisable value) from the total investment amount needed for the new project (Luke, 1997).
- *Depreciation and accounting book value.* Depreciation is ignored in discounted cash flow calculations because it has no direct influence on cash in- or outflow. The book value of an asset represents the difference between the original capital outlay and accumulated depreciation, but its value does not bear any relation to the true realisable cash value of the asset.
- *Income taxes.* Due to the definite influence of tax on the cash flow of an investment (cash outflow), comparisons should be made only after taxation has been taken into account.
- *Overhead costs.* Only those overhead costs specifically associated with particular investments, or the differences in overheads between different

investments, are taken into account. In practice, it may be difficult to allocate these values to different projects and thorough analysis is therefore necessary.

The basic principle of this method is to calculate the net present value (NPV) of the capital investment. It is done by calculating the present value of all future estimated cash flows (discounting) and then subtracting the NPV of the original investment from the sum of the annual discounted cash flows.

The discount rate that is used will be equal to a specific norm or standard, which company management has set and which can be adapted to take full cognisance of all risk factors. This rate should equal the opportunity cost or the marginal cost of capital to the company.

It should be borne in mind that the periods of comparable projects or mutually exclusive projects under consideration should be equal. If the time horizons of the relevant projects are not equal, techniques must be used to equalise such periods.

The NPV method is applied as follows:

$$NPV = \frac{FV_1}{(1+K)} + \frac{FV_2}{(1+K)^2} + \frac{FVn}{(1+K)_n} - I_0$$

where:

NPV	=	Net Present Value
FVn	=	Net cash flow in year n
K	=	Critical rate of return
I_0	=	Investment in year 0

If the NPV > 0 (is greater than zero) then the project is acceptable.

The advantages of the NPV method are given below:

- This method is theoretically and logically consistent with the principle of maximisation of shareholders' interest.

- Cash flow for the total life span is taken into account, including the residual value of the specific asset (if applicable).
- The depreciation of the value of money over time is acknowledged.
- The recovery of the original investment is evaluated.
- Different discounting rates can be used during the life spans of the projects.

The disadvantages of the NPV method are listed below:

- This technique is not always as readily understandable as other investment analysis techniques.
- It is not easy to establish an appropriate discount rate, and the effectiveness of using the company's marginal cost of money as the discount rate has been questioned.
- Given the discount rate, it is still difficult to evaluate the difference between the net present values of projects where large discrepancies exist between the extents of the projects being compared. However, by expressing the result as a ratio (e.g. R/ha or R/m^3 in forestry), this problem is overcome.
- A degree of uncertainty exists regarding the company's ability to realistically evaluate future capital inflows.
- The implicit assumption that capital inflows can be "re-invested" at the same rate as the discounting rate for the duration of the project's life span is not always true.
- The internal profitability of the project can differ substantially from the given discount rate, because it will not necessarily be equal to the critical profitability.

The selection of a discount rate for the NPV analysis is important. It is firstly necessary to decide on whether a nominal or real discount rate will be used. Klemperer (1996) suggests that the real rate should be used as it is more stable than the nominal rate, which is more susceptible to inflation rate fluctuations. Das Falcao (1998) used a real discount rate of 3,5% for South Africa in a forestry evaluation study that he conducted.

The NPV approach however, remains one of the most theoretically acceptable approaches (Brigham, 1985; Luke, 1997; Sizer, 1989).

3.4.1.2 Internal Rate of Return (IRR)

This technique is an alternative which can be used to evaluate projects. The internal rate of return (IRR) equals the true rate of return, which will be obtained from a project over the life span of the project. The IRR is that rate of return (K) which, when it is applied, will equalise the present values of both the cash inflows and the cash outflows. In other words, it is the discount rate which will make the NPV of the project equal to zero (0).

Another way of describing it is that the IRR is the maximum rate at which capital can be borrowed without compromising the interests of the shareholders. The IRR of a project can be calculated by applying the following formula:

$$I_0 = \frac{FV_1}{(1+K)^1} + \frac{FV_2}{(1+K)^2} + \frac{FV_3}{(1+K)^3} + \frac{FV_n}{(1+K)^n}$$

where:

I_0	=	Internal Rate of Return
FVn	=	Net cash flow in year n
K	=	Critical rate of return

When the IRR equals or is greater than the critical rate of return, the project is acceptable, otherwise it would be eliminated from the investment options under consideration (Luke, 1997).

The advantages of the IRR approach are given below:

- As in the case of NPV method, the IRR method is seen as a theoretically correct approach.
- The depreciation of the value of money over time is one of the key positive factors in this method.
- The financial attraction of a project is expressed as a rate of return (percentage), which can easily be compared with the accepted critical profitability of the company. Projects having an IRR lower than the critical rate of return are rejected.

- This method automatically provides for the recovery of the initial and any subsequent investments.
- The IRR approach can be used to distinguish between projects having equal project life spans, equal and unequal total investment amounts, as well as equal and unequal cash inflows over different periods of time.

The disadvantages of the IRR approach are given below:

- The IRR approach does not distinguish between alternative projects of differing sizes. It can be to the advantage of the company to accept a project with a lower IRR if the cash inflow is spread over a longer period, in contrast to a project having a high internal rate of return but a shorter life span.
- The implicit assumption that all capital funds that become available can be re-invested at the calculated eventual IRR rate, is sometimes questioned.
- It is also possible that projects can even have two or more solutions for the internal rate of return. Such an alternative rate can even have a negative factor. Circumstances such as this make the interpretation of results from the IRR approach very difficult.
- The IRR method cannot be used for the ranking of projects.

(Brigham, 1985; Luke, 1997; Sizer, 1989)

3.4.2 Machine cost calculations

This method assumes:

- that costs are uniform over the life of a machine, that is they do not increase or decrease with machine age;
- they ignore the time value of money;
- they ignore income taxes;
- they are very sensitive to the depreciation assumptions made (Greene, 2001).

Total equipment costs include all costs accrued from buying, owning, and operating equipment. For analysis purposes, equipment costs can be grouped into fixed costs, operating costs, and labour costs.

3.4.2.1 Factors affecting machine cost calculations

Miyata (1978) summarises factors that should be taken into account when preparing a machine cost calculation (MCC).

- *Equipment specifications.* Model, type of equipment, net horsepower at flywheel, capacity of crankcase and hours between oil changes, are necessary to calculate the cost of equipment per unit of time. They can be obtained from the equipment specification sheet, the owner's manual, or both.
- *Initial investment (P).* This is defined as the actual equipment purchase cost, less the tyre cost, regardless of whether the equipment is purchased at full price or discounted rates.
- *Salvage value (S).* This is defined as the amount that equipment can be sold for at the time of its disposal. The actual salvage value of equipment is affected by current market demand for used equipment and the condition of the equipment at the time of disposal. However, estimating the future salvage value of equipment is very difficult because it is based on the future market value and the unknown condition of the equipment at the time of its disposal. The estimates come from owners themselves or from manufacturers or dealers. As a rule of thumb, the salvage value can be considered 20 percent of the initial investment cost.
- *Economic life (N).* This is the period over which the equipment can operate at an acceptable operating cost and productivity. The economic life is generally measured in terms of years, hours, or mileages (trucks and trailers). It depends on two factors -physical and functional impairment.
- *Scheduled operating time (SH).* Scheduled operating time is the time during which equipment is scheduled to do productive work (Miyata 1978). The time during which a machine is on standby is not considered scheduled operating time. If a spare is replacing a machine, the scheduled operating time of the replaced machine ends when the replacement arrives on the job. The scheduled operating time of the replacement begins when it starts to move toward the job. Scheduled operating time is determined as follows:

If a piece of equipment is scheduled for use 8 hours a day and the possible estimated working days (subtracting weekends, holidays, bad weather days), are 250, then:

SH = 8 *hrs/day* x 250 *days/yr* = 2 000 *hrs/yr*

- *Productive time (H).* Productive time is that part of scheduled operating time during which a machine actually operates (Rolston 1968). Only rarely would scheduled operating time and productive time be equal for logging equipment, due to delays such as mechanical breakdowns, personnel, and weather. Productive time (H) divided by scheduled operating time multiplied by 100 is termed percent machine utilisation.

For example, suppose that a grapple skidder is scheduled for 2 000 operating hours per year and that the machine utilization is 67%. Then the estimated productive time per year is:

H = 2 000 *hrs/yr* x 67% = 1 340 *hrs/yr*

3.4.2.2 Components of a machine cost calculation

a) Fixed Costs

Fixed costs do not vary with hours of operation. They are neither affected by the amount of equipment activity nor output and are incurred regardless of whether a piece of equipment is used or not. Fixed costs include depreciation, interest, insurance and taxes.

- *Depreciation.* A piece of equipment loses its value with time and possesses only salvage value (or trade-in value) at the time of trade-in. The basic objective of the depreciation schedule is to recover the initial investment cost of equipment each year over its estimated economic life. The method for calculating depreciation is ordinarily determined by its planned or desired effect on profit and income taxes through the economic life of equipment. The three common methods generally used to compute depreciation are: straight line, declining balance, and sum-of-the-year's-digits. These three methods are reflected in Figure 3.33. The most common method used in machine cost calculations is the straight line method.

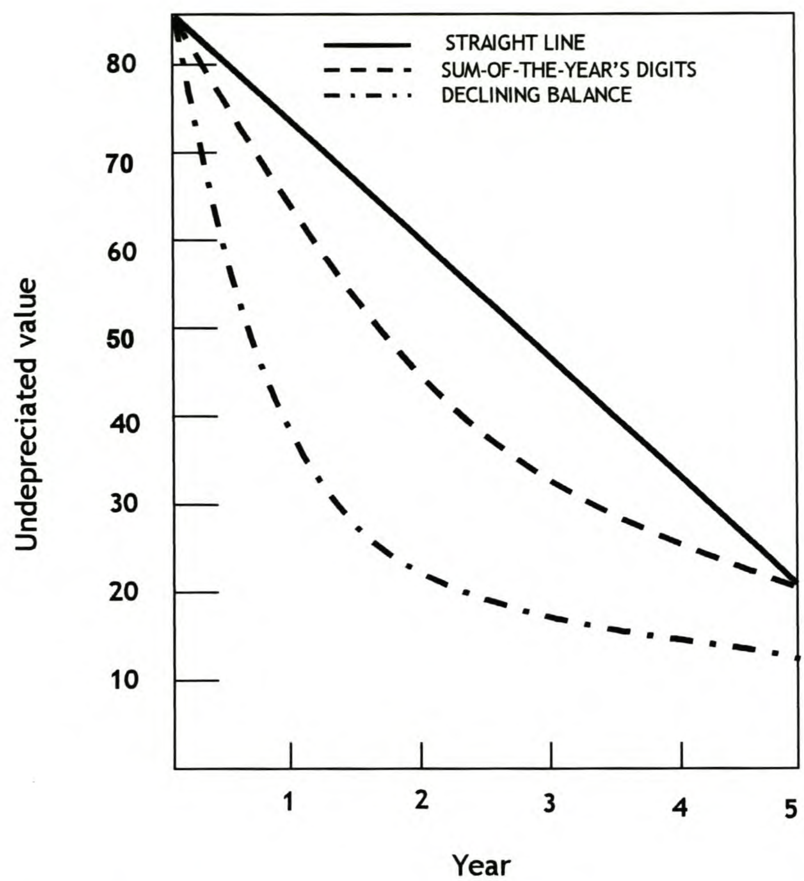


Figure 3.33: Various depreciation methods applied to equipment

- *Interest, insurance, and taxes.* Interest is the cost of using funds over a period of time. Investment funds may be borrowed or taken from savings or equity. If borrowed, the lender generally establishes the going interest rate. Interest rates may vary with locality and lending institution. If the money comes from personal savings or established equity, then an opportunity cost, or the rate this same money would earn if invested elsewhere should be used as the interest rate. This would reflect the nominal interest rate of the investment. In South Africa, companies would use the prime rate as a rule of thumb for interest (Coetzer, 2001). As a rule of thumb, 5 percent of the average value of yearly investment may be used for insurance, and 2 or 3 percent for overheads. The charges for interest, insurance, and overheads are generally applied to the average value of yearly investment.

b) Operating costs

Operating costs, unlike fixed costs, change in proportion to hours of operation or use. They depend on a host of factors, many of which are under the control of the operator or the equipment owner to a certain extent.

- *Maintenance.* These include everything from simple maintenance to the periodic overhaul of engine, transmission, clutch, brakes, and other major equipment components. Storage costs and preventive maintenance are also included. Operator use or abuse of equipment, the severity of working conditions, maintenance and repair policies, and the basic equipment design and quality, all affect maintenance and repair costs.

  The cost of periodically overhauling major components may be estimated from the owner's manual and the local cost of parts and labour, or by getting advice from the manufacturer. Another owner's experience with similar equipment and cost records under typical working conditions are valuable sources. If experienced owners or cost records are not available, the hourly maintenance and repair cost can be estimated as a percentage of hourly depreciation cost from the following tabulation (Warren 1977):

Machine	*Percentage rate*
Crawler tractor	100
Agricultural wheeled tractor	100
Rubber tyred skidder (cable)	50
Rubber tyred skidder (hydraulic grapple)	60
Loader(cable)	30
Loader (hydraulic)	50
Chainsaw (include maintenance)	100
Feller-buncher	50

To estimate hourly maintenance and repair cost, multiply the percent rate by the depreciation cost and divide its product by productive time per year.

The nature of operating costs and fixed cost as a function of hours of operation and use is reflected in figure 3.34.

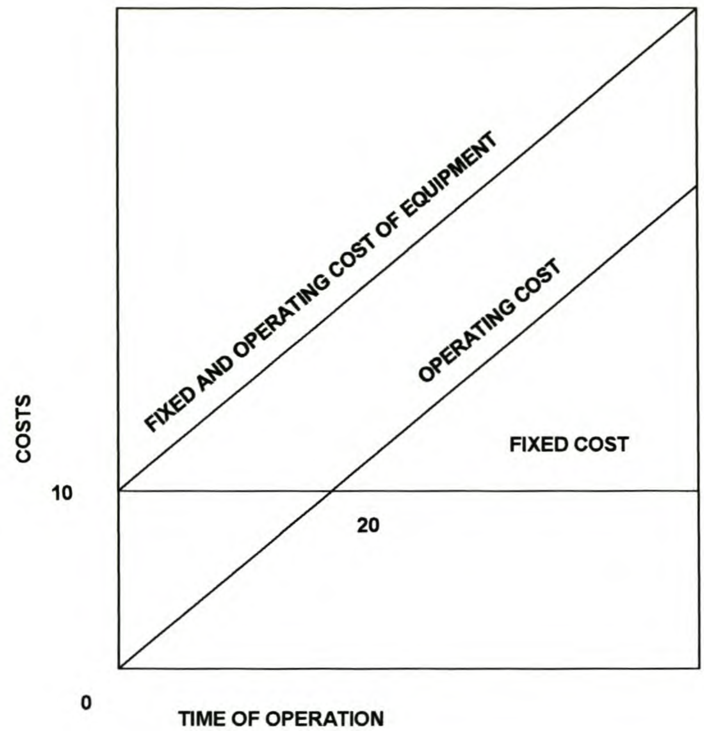


Figure 3.34: Nature of operating costs and fixed cost as a function of hours of operation and use

- *Fuel.* The fuel consumption rate of a piece of equipment depends on the engine size, load factor, the condition of equipment, the operator's driving habit, environmental conditions, and the basic design of the equipment. Determine the hourly fuel cost by dividing the total fuel cost by the productive time of that equipment.
- *Lubricants.* These include engine oil, transmission oil, final drive oil, hydraulic oil, grease, and filters. The consumption rate varies with the type of equipment, environmental working condition (temperature), the design of equipment, and the level of maintenance.

  Derive hourly lubricant cost by dividing the total lubricant cost by the productive time of that equipment.
- *Tyres.* Some cost analyses include tyre cost in the initial investment cost. We consider tyre cost part of the operating cost because of their shorter life span. This cost is affected by the operator's driving habits, environmental and terrain conditions, wheel alignment, tyre maintenance and the local price.

  The hourly tyre cost is obtained by dividing the total tyre cost (including tyre and recaps) and maintenance by the total life of tyre and recaps.

c) Labour cost

Labour cost is the cost to keep an operator on the job; it may be on an hourly basis, a per unit of output basis, or a combination of both. An employer must also contribute to the Unemployment Insurance Fund (UIF), Workmen's Compensation, and other programs (Miyata, 1978).

3.5 Conclusion

This Chapter gives an overview of the forecasting and costing techniques that are relevant to the forecasting and costing of the Forest Engineering value chain. The individual techniques can be applied in value chain planning or forecasting. Examples of this are given below:

- Time series forecasting is used to establish the trends of certain variables that affect timber harvesting and transport systems.
- Delphi studies should be used to establish future Forest Engineering trends.
- Benchmarking is commonly used by companies to determine their harvesting and/or transport cost position relative to other companies.
- Environmental scanning and brainstorming are commonly used in companies to plan for their future Forest Engineering strategies.

Chapter 3 also evaluates various approaches that can be used to evaluate the Forest Engineering value chain. The evaluation includes traditional financial evaluation and traditional MCC approaches. The financial evaluation methods assist in understanding how various projects (value chains) can be compared to each other, while the MCC shows what factors need to be considered within such a comparison.

What is required is to find the correct combination of both forecasting and costing techniques that will allow for the accurate long-term forecasting of the relevant machines and equipment that will constitute the future Forest Engineering value chain. Chapter 4 uses the information generated in this Chapter to combine the relevant methods into a powerful tool to forecast the Forest Engineering value chain.

4. DEVELOPMENT OF A FOREST ENGINEERING FORECASTING METHOD

4.1 Introduction

The Chapter commences with a description of the principles of forecasting and how forecasting techniques are to be used in order to develop a sound forecasting method. With this as background the relevant Forest Engineering factors are identified, which need to be considered during the development phase.

The relevance of each forecasting technique, to the development of a forecasting method, is given in Chapter 3. Chapter 4 focuses on the development of a method that successfully combines the various forecasting techniques that have been discussed. However, the methody requires the inclusion of a sound costing approach, which is required to select the preferred value chain for the future. A preferred costing method is thus included, considering both the comparison of value chains with one another, as well as the factors that should be included within the comparison (based on the traditional MCC).

The chapter concludes with a systematic discussion of why a specific technique was selected and how it is to be applied when using the proposed forecasting method.

4.2 The principles of forecasting

Four elements are identified by Twiss (1992) in order to provide an adequate basis for decision-making. These are:

- qualitative;
- quantitative;
- time; and
- probability.

The first step must be to define what should be forecast. What is the purpose and how will it be used? This is the qualitative element. It is likely to require divergent thinking to embrace technologies or developments, which depart from those that have been significant in the past. Thus, it would have been of no benefit to a horseshoe manufacturer in 1900 to forecast the trends in the abrasive resistance of metals, at a time when attention should have been focused on the emerging developments in motorcar technology.

Having established what to forecast, it is then necessary to consider how the technology can be represented in quantitative terms. A measure is required. In some situations, it may be difficult to define a precise measure and some form of judgmental quantification must be sought. The forecast must state whether it is for a single technical approach or for a more general technology.

The third element, time, is self-evident since forecasting is essentially about relating a future condition to the time when it occurs. The investment of financial resources causes that progress to occur. It may be a single point in time or a time span. In either case, the time of the forecast should be clearly stated (Martino, 1983). Part of this includes the establishment of how well the past represents the future (Adam and Ebert, 1978).

Finally, it is necessary to incorporate some indication of the uncertainty, which is associated with every forecast. However difficult it may be to derive this, it is essential that every forecast be associated with a probability. There is therefore a cost/accuracy trade-off in selecting a forecasting approach. The more sophisticated approaches tend to have relatively high costs of implementation, but they often provide more accurate forecasts, resulting in lower operating costs. Figure 4.1 illustrates one hypothetical cost situation. For any forecasting situation there is an optimal cost region where reasonable accuracy is obtained. The goal in forecasting is to operate somewhere in this region.

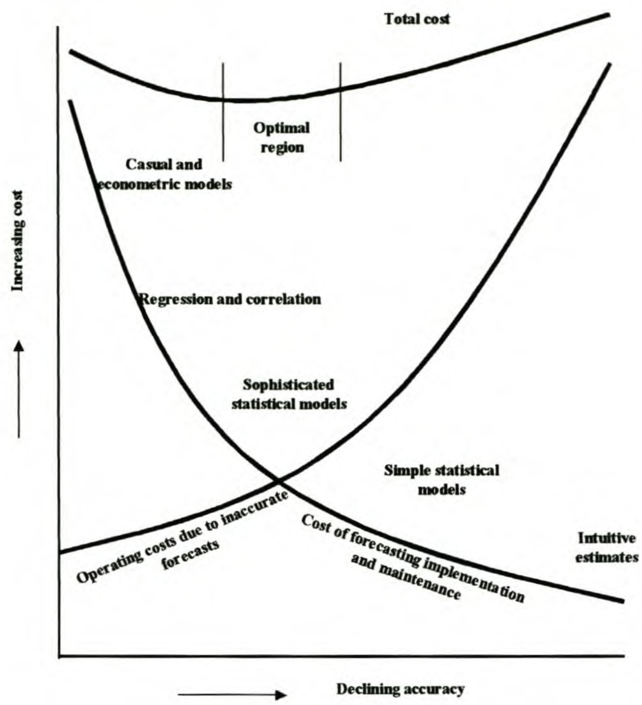


Figure 4.1: Cost/accuracy trade-offs in forecasting (Adam and Ebert, 1978)

Costs to be considered in method selection are implementation costs, systemic costs, and forecast error costs, the latter being the more complex to evaluate. They depend upon noise in the time series, the form of the demand pattern, the length of the forecasting time horizon, and the measure of forecast error. There is no one model that is best for all demand patterns. Another cause of uncertainty arises from events, which can be foreseen but not forecast. The inability to forecast the timing of these foreseeable events does not mean that they can be ignored.

In summary, several questions need to be asked when selecting a forecasting approach. Firstly, what is the purpose of the forecast. In other words, how is it to be used? Exactly what is being forecast? Obviously, the approach that should be selected depends on what the forecast will be used for. Secondly, the manager must ask about the conversion system in which the forecasts will be used. Is this system stable or dynamic, large or small, technologically simple or complex? Both the costs of obtaining the forecast and the accuracy that is possible should be carefully considered.

4.3 Using forecasting techniques to develop a forecasting method

One of the first priorities in setting up a forecasting activity must be to ensure that a procedure is initiated for the collection of contemporary data which can be used in the future. Thus, with the passage of time, the quality of the data will improve progressively as will the accuracy that can be expected from the forecast/s. The questions to be addressed by the forecaster are:

- What data do I require?
- Where do I find it?
- How do I interpret what I have obtained?
- How accurate is it?
- How can I ensure that from now on data on new developments and the progress of existing technology are identified and recorded systematically for future use?

In many circumstances, the resources available to the forecaster have serious limitations. This does not invalidate their usefulness but it does mean that forecasting cannot be regarding as an exact science. Twiss (1992) explains how forecasting and creativity are closely associated and now many aspects of the two processes have a great deal in common. The way in which the mind operates when it is generating creative ideas is imperfectly understood. It often appears to be a random process in which an idea occurs from a flash of inspiration, insight, or from an intuitive feel for what may be possible. However, if this happens, it can only be the starting point for it is then necessary to evaluate whether the concept is technologically and economically feasible and could meet a market need. Often an analogous process occurs in forecasting. A possible future, which may be a normative technological objective is envisaged, although there may be no confidence that it represents a feasible possibility. It is then necessary to carry out detailed forecasts to establish whether it does indicate a future that is achievable. In other words, it is necessary to construct a path from the present to the desired future which can be justified through a logical argument (Figure 4.2). Forecasting can provide that logic. This is the basis for the normative forecasting techniques. Described in this way, it can be seen that neither creativity nor forecasting should be regarded as mechanistic procedures. Two stages are evident:

- Insight and imagination to originate the idea of what might be possible.
- An evaluation, using formal methodologies, to establish whether the idea provides a feasible basis for a practical development.

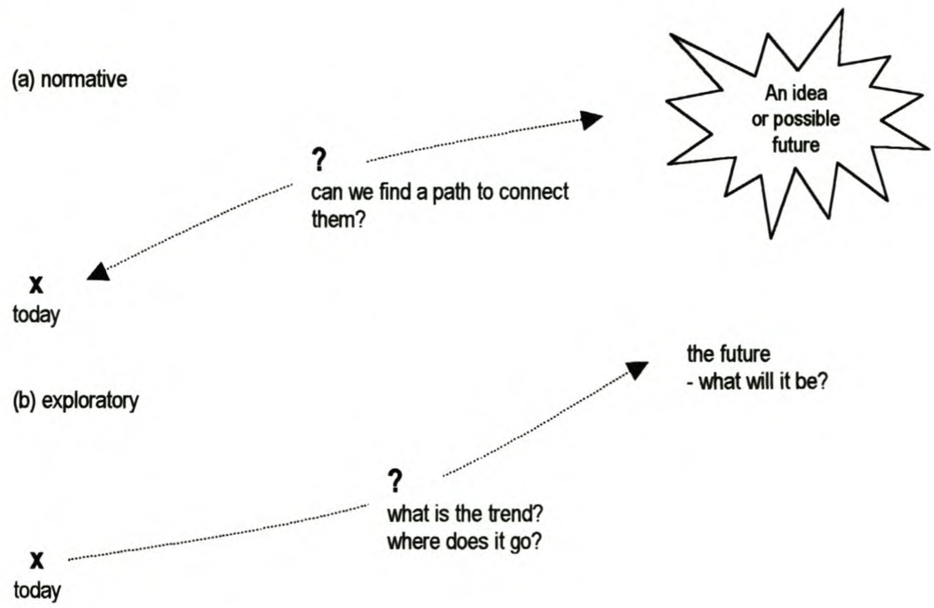


Figure 4.2: The roles of forecasting (Twiss, 1992)

In making a forecast, the shape of the growth curve may be describable by one of these patterns or by several in combination. For a pure technology forecast, an S-curve in isolation is often sufficient in itself. For a short-term market forecast, required for the production planning of a new product, it may be necessary to consider a combination of:

- the rate of substitution of the new product for the old (S-curve);
- the long-term growth of the total market (regular growth);
- the state of the economy (business cycle);
- seasonality of demand (12 month cycle); and
- any possible disruptions to the growth pattern (discontinuities).

A different situation arises with many long-term forecasts where there may be such a wide range of possible developments that it becomes difficult to decide what to focus upon for detailed analysis. Furthermore, the expertise to make the judgments may not exist within the organisation making the forecast. Thus, it becomes necessary to involve external experts, often international, who are the people best able to give a considered judgment of the development of technology with which they are associated. The Delphi technique is one method of obtaining this input, which would include the subjective forecasts of these developments together with the dates when they are likely to occur. Technological forecasting is also of importance to strategic and operational management and can compliment the development of scenarios (Tschirky, 1994).

The industrial life cycle can be used as a forecasting tool. By considering the past evolution of the industry, it is possible to establish the current position on the cycle. This can be used to forecast where the industry is likely to be at times in the future, but because technological developments have long lead times, it gives a strong indication of where the technological resources should be deployed now in order to satisfy these future needs.

Sensitivity analysis, on the other hand, approaches the problem from the opposite direction. It starts by taking the central forecast and asking a series of "what if" questions. A sensitivity analysis indicates the significance of any changes from the assumed conditions. In effect, this approach states "this is our best forecast under the stated assumptions but if we are wrong these are the consequences of the errors". This indicates how sensitive the outcome of the decision would be to errors in each of the elements of the overall forecast. In practice this is likely to show that it would be robust over a considerable range for some factors but exceedingly sensitive to others. Those that are robust can then be ignored and attention focused on the others, which might be refined by further work. In a few cases, the sensitivity may be such that the risks associated with the uncertainties are so great that the proposal being investigated should be abandoned.

Figure 4.3 is a summary of the application of several forecasting techniques, which have not all been discussed in chapter 3, as they are not all relevant to this study. What is important is to note that various techniques have specific application depending on the development of the life cycle of the industry or product. Chapter 2 shows that machine manufacture for harvesting and trucks used in timber transport are in their mature stage. Even CTLM machines have been available since the 1970's in Scandinavia. The specific forecasting method developed in this study needs to focus on the medium- to long-term, hence the need to focus on the techniques outlined in stages 2 and 3 of the life cycle.

Stage 1	Stage 2	Stage 3 & 4
1. Rate of advancement of technology 2. Level of performance of future products? Technique - time series & trend extrapolation - S-curve 3. Rate of decline of product unit cost Technique - experience curve	1. How rapidly will market grow? Technique - Fisher-Pry - pre-cursor driver 2. How may product performance be improved? Technique - technology substitution - morphological analysis 3. How to achieve competitive advantage Technique - attribute substitution - technology substitution	1. How can manufacturing costs be reduced? Techniques - trend extrapolation & time series - Fisher-Pry substitution 2. How can product in-use life be extended Technique - technology substitution 3. How can medium-term threats be identified? Techniques - Fisher-Pry product substitution - technology monitoring 4. What technologies must be exploited to provide technology based business diversification? Techniques - Delphi - Scenarios - Technology substitution - trend exploitation and time series
1	2	3 4

Figure 4.3: Forecasting techniques and their application (after Twiss, 1992)

4.4 Key variables in the Forest Engineering value chain

Forest Engineering has certain fundamental factors, which require consideration when designing the forecasting method. The factors summarise the findings in Chapters 2 and 3. The forecaster needs to understand the factors in order to apply the principles of forecasting and to develop a forecasting technique, as described in Paragraphs 4.2 and 4.3. These factors are given below:

- Forest Engineering, consisting of timber harvesting, forest roads and transport constitutes the bulk of costs in the forestry value chain. The method should thus forecast cost effective solutions.
- Forest Engineering change drivers are global in their nature. This requires a strong emphasis on global trends in the forecast.
- Forestry has become an acute international issue, particularly with regard to harvesting operations in relation to their impact on the physical environment.
- Forestry machine suppliers have become global players, with the overwhelming bulk of equipment manufactured by a handful of suppliers. Certain countries are clear producers of machine technology, whilst others are the consumers thereof.
- Each country and/or region has its own unique circumstances. These need to be considered in the analysis.
- Due to the pace of global change, it is not possible to produce a single forecast of the future. Scenario analysis is a commonly used technique in the business world of today and is well suited as a tool to forecast the future Forest Engineering environment.
- Trends are available for a great deal of the change drivers relevant to Forest Engineering. Examples are the cost of fuel, the cost of labour and exchange rate fluctuations. These trends should be extrapolated into the future in order to establish the "tunnel" within which variables could possibly deviate in the future.
- Forest Engineering is primarily a technology driven industry, where productivity improvements are obtainable only through continuous innovation and improvement of the machines and equipment used. Mechanisation and automation have continuously increased over time. The labour component is continuously reducing in order to keep costs down. Factors such as fuel efficiency and general low energy consumption per m^3 of timber produced are the driving force in machine improvements through technology.
- Because of the increased sophistication of logging equipment, a forecast must consider the ability of a country or region to utilise this technology. This is reflected in the ability of local suppliers to guarantee acceptable levels of machine availability. The skill levels required to operate the machine also requires consideration.

Large amounts of capital are invested in harvesting machines. Extreme alternative systems could be considered for the future – from a totally labour intensive system, to a much mechanised one. This requires that an objective and accurate financial analysis system be used. Traditional harvesting and transport systems do not qualify as such, primarily because the time value of money is not considered. The most appropriate analysis method is the NPV method, which also allows for the ranking of projects. The use of the NPV method is discussed in more detail in paragraph 4.5.

Considering the extremities in the alternatives to be considered, it is important to clearly identify relevant systems that could possibly be the most appropriate for the future. An individual who has a clear understanding of the region/country for which the forecast is being conducted should therefore preferably conduct the forecast. Such an individual would be ideally suited to configuring various value chains that need to be evaluated and to comparing their results.

Assumptions form the basis of the forecast. For each analysis, the assumptions need to be clearly stated and defined.

Considering the above factors, the forecasting techniques available have been combined into the method illustrated in Figure 4.4. The Figure indicates the specific analysis which is required in the first column and gives the forecasting tool that will be used in the second column. It must be noted that the final action refers to the formulation of a strategy to meet future outcomes. It remains imperative that this step be included in the forecast, as the absence thereof will minimise the potential benefits of the whole exercise.

4.5 Forecasting method

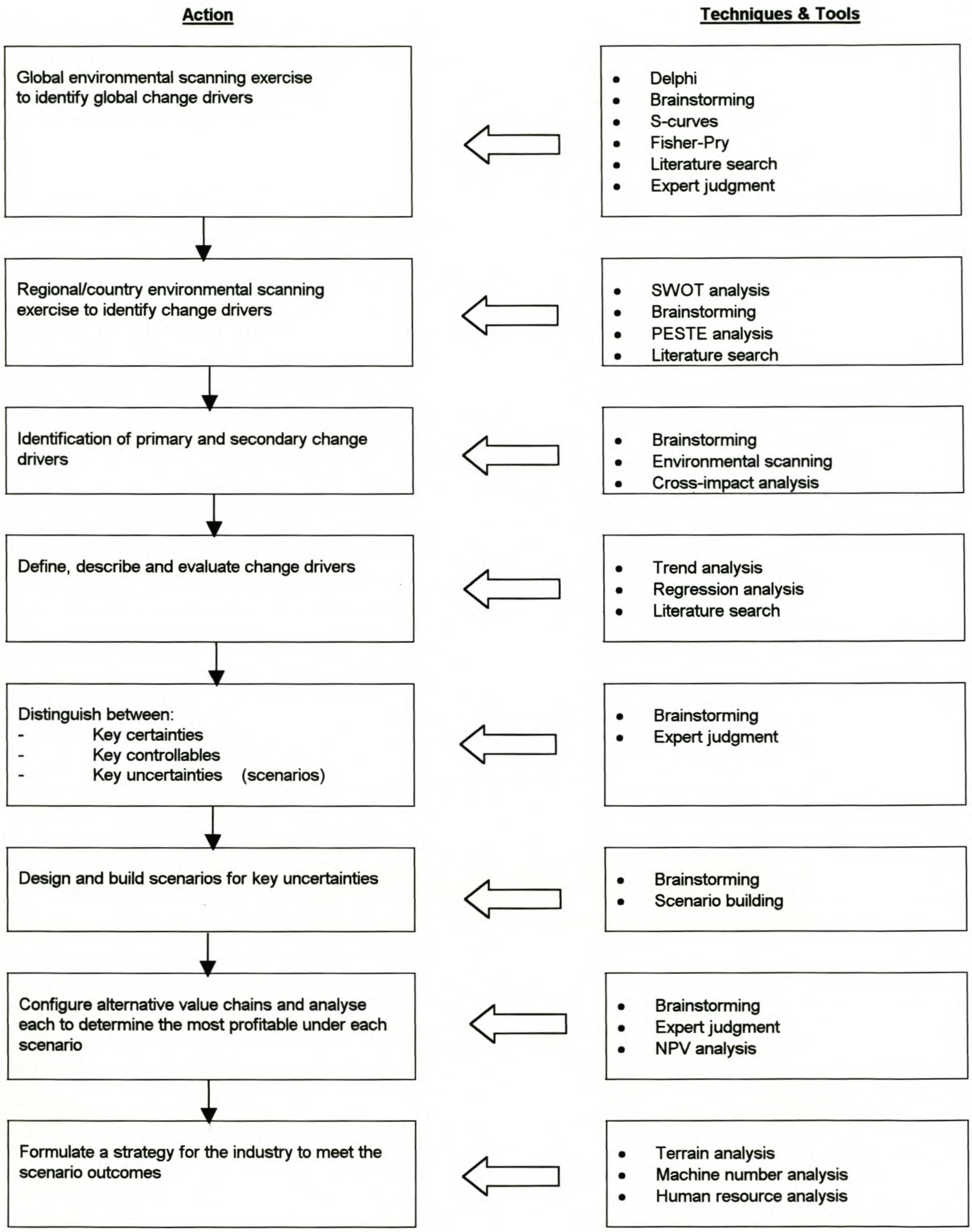


Figure 4.4: The forecasting method for the Forest Engineering value chain

a) Forecasting period

The forecaster must decide on the period for which the forecast is to be prepared. This would be a function of how the final results will be used.

b) Global environmental scanning exercise

The exercise commences with the forecaster establishing the global change drivers affecting the Forest Engineering value chain. This is required due to the globalisation of all large industries, including forestry. The forecaster must at this stage have determined whether the geographic region for which the forecast is being prepared is a producer or consumer of forest machine technology. The foundation for the forecast will be incomplete if only local change drivers are considered.

The global change drivers are determined, preferably by using the Delphi technique. This should not be necessary where the forecaster can rely on recent literature, expert judgment and/or brainstorming to determine the relevant change drivers. The process should include a ranking of the key change drivers to allow for the identification of the major factors that will be responsible for change.

If the forecaster is concerned about the discontinuation of certain machine technologies, S-curves and/or the Fisher-Pry technique should be used to establish market trends. This becomes more important if a forecast exceeds a period of 5 years, when discontinuities may occur within certain systems. An example would be the level of substitution of CTLM harvesting machines with TL machines.

c) Regional/country environmental scanning exercise

Once the global position has been established, the forecaster can focus on the factors that will impact directly on the region/country for which the forecast is being prepared. The first step will be to complete a SWOT analysis, considering the key global change drivers identified during the global environmental scanning exercise. This will give the forecaster an overall view of the strengths and weaknesses of the particular region/country and the external opportunities and threats that need consideration. Brainstorming is considered the most appropriate method to use for the SWOT analysis. This could be done through either brainstorming with a group of experts collectively, or, alternatively, by brainstorming on an individual basis.

The SWOT analysis would form the basis for a comprehensive environmental scanning exercise for the relevant region/country. The most appropriate tool to use is considered the PESTE analysis. The forecaster should carefully focus on those forces relevant to the Forest Engineering value chain. Examples are:

- *Political.* Legislative changes impacting on harvesting and transport; Political stability of the region/country.
- *Economical.* Example of factors which need consideration are fuel price trends and exchange rate trends;
- *Social-cultural.* Perceptions of communities towards harvesting practices; wage rate trends; education levels of workers in forestry; health and safety risks.
- *Technological.* Trends in countries that are exporters of machine technology; the effect of potential discontinuities of certain machine ranges; the impact on after sales service; and operator training of more sophisticated machines
- *Environmental.* The impact of various machine types on the soil; the cost/benefit of running environmentally friendlier equipment.

d) Identification of primary and secondary change drivers

With the environmental scanning exercise as background, the primary and secondary change drivers that will affect the future Forest Engineering value chain can then be identified. The core of this part of the exercise is to determine the inter-relationships between the change drivers that have been identified. All the primary and important secondary change drivers are to be considered. The appropriate tool to use to identify these inter-relationships is considered the cross-impact matrix. Once again, only the high cross-impacts are important. If the forecaster believes that some of the medium cross-impacts are important, then these may be included in the list of relevant cross-impacts.

e) Scenario building

The forecaster can now move to the building of scenarios, based on the information that has been gathered in the preceding exercises. Firstly the high cross-impacts are to be divided into:

- key certainties;
- key controllables; and
- key uncertainties

Because the "key certainties" are known and the "key controllables" can be controlled, the "key uncertainty" change drivers are used to develop scenarios. A great deal of creativity is required during this part of the forecasting exercise, as it forms the core of forecasting of the final Forest Engineering value chain. Once the various scenarios have been determined (not more than four), a story is written so as to paint a picture of the operating environment within which the future systems will operate. This picture is primarily based on the results of the cross-impact matrix.

f) Identification of potential Forest Engineering value chains

The forecaster now needs to use creativity, the knowledge gained to date and brainstorming to configure probable alternative value chains that could reflect the various scenarios described above. This requires the forecaster to have a sound understanding of both the Forest Engineering discipline and the environment within which the future Forest Engineering value chains will operate.

g) Identification of the most profitable value chain under each scenario

Using the NPV method (one of the DCF techniques available), the forecaster then identifies the most profitable value chain for each scenario. This method is used because it allows the ranking of various value chains against each other. A ratio is determined for each system by dividing the discounted amount over the relevant period by the volume of timber removed by the system. It is important to use equal periods for each of the alternative systems being evaluated. Because this is primarily a costing exercise, the value chain with the lowest negative value is the most appropriate one. NPV evaluations allow for both cash inflows and cash outflows. It is thus possible to allow for advantages of additional income from one system, as opposed to another. For example, if a feller buncher causes less breakage than chainsaw felling, the marginal income advantage generated by the feller buncher can be entered as an income stream (cash flow) over the period.

h) Formulation of a strategy

Although it is not part of the forecasting procedure, it remains critically important to formulate a strategy for the region/country for which the forecast is being prepared. This will allow for the pre-emption of the negative drivers and the capitalisation on the positive ones, and in so doing, allow for the preferred scenario to be realised. The strategy should include the extent of the application of the preferred value chains for the relevant region/country. This will require a sound knowledge of the prevailing stand and site conditions. If the forecasting period is long enough, then it would be advisable to plan for the upgrading of the human resources required to service the identified systems, through appropriate education and training strategies.

4.6 Conclusion

The approaches to forecasting are firstly discussed in the beginning of this chapter, followed by a summary of the important criteria relevant to the Forest Engineering value chain that need to be considered in the development of an appropriate forecasting method. It then proceeds with the development of a unique method to forecast the Forest Engineering value chain. The chapter concludes with a description of why the method is configured in this unique way and how it should be used. In order to test the validity of the proposed method, it is necessary to test it in a case study. This is done in chapter 5, in which the method is tested through the development of a forecast and a strategy for the South African forestry industry.

5. FORECASTING THE SYSTEMS IN THE SOUTH AFRICAN FOREST ENGINEERING VALUE CHAIN

5.1 Introduction

The forecasting method, developed in Chapter 4, is applied in this Chapter to verify its validity. A forecasting period is defined, followed by a discussion of the forecasting method, specifically for the South African forecast. Thereafter, a systematic implementation of the method follows. The forecast includes a comprehensive Delphi study to identify future timber harvesting change drivers, future harvesting systems, the role of contractors and the human resource requirements of harvesting managers and contractors. It also includes an analysis of machine substitution curves by using the Fisher-Pry technique. The substitution is specifically targeted at identifying the substitution of TL machines by CTLM machines.

A comprehensive environmental scanning exercise is included of South Africa, focussing on factors, which will influence the systems in the Forest Engineering value chain. With this as background, a scenario analysis is completed, culminating in the identification of 14 potential Forest Engineering value chains for South Africa.

The scenario analysis gives a sound platform for an in-depth costing exercise of the14 systems and their relevance to each scenario. The costing exercise required the development of a DCF model, which was used for the ranking of alternative systems within each scenario. The NPV method is used in this regard.

The chapter concludes with the required strategies by the Forestry Industry to manage towards the required outcomes for the future. Projected machine numbers for the preferred systems are also given.

5.2 The forecasting period

As described in Chapters 3 and 4, the further one forecasts into the future, the less accurate the forecast. Contrary to this, if the forecast is too short, then the ability for new technologies to take effect is reduced. The time frame for this forecast has been set for the year 2010.

The reasons for this are:

- The period is short enough to obtain reliable forecasts on key certainties and key controllables;
- The period allows for sufficient time for key change drivers to take effect; and
- The period allows sufficient time for the South African Forestry Industry to prepare a strategy to meet the demands of the future.

5.3 Application of the forecasting method to this forecast

The method developed in Chapter 4 can be used to analyse any part of the value chain or the whole value chain. Although this forecast is prepared for the total Forest Engineering value chain, special emphasis is placed on timber harvesting (felling, extraction, processing and loading).

The forecasting method developed in Chapter 4 is used to conduct the forecast. The application of the method can be segmented into the steps, as shown in Table 5.1. The method shown in Figure 4.4 forms the core of the steps shown in Table 5.1.

Table 5.1: Procedure in application of the forecasting method

Action	Tool	Reason
1. Global environmental scanning exercise to identify key global change drivers	• Delphi • Fisher-Pry • Expert judgment • Literature search	• Globalisation • SA consumer of technology
2. Produce a profile of the requirements of a harvesting forester and harvesting contractor in South Africa	• Delphi	• To guide tertiary institutions and training institutions regarding curriculum content
3. South African environmental scanning exercise to identify key change drivers (based on the results of 1)	• Brainstorming • SWOT analysis • PESTE analysis	• Study results are specific to South Africa
4. Define each change driver in detail and describe in the South African context.	• Literature search • Trend lines	• Prevent ambiguities in further analysis
5. Conduct a cross-impact analysis of the change drivers identified in 2	• Cross-impact matrix	• Identify key inter-relationships • Provide structure for scenario analysis
6. Obtain relevant trends and conduct forecasts, where possible of each driving force	• Regression, trend analysis • Literature search	Required to distinguish between: • Key certainties • Key controllables • Key uncertainties
7. Distinguish between: - key certainties - key controllables - key uncertainties	• Brainstorming • Expert judgment	• Required to determine alternative scenarios
8. Design and build scenarios for key uncertainties	• Scenario building • NPV analysis of systems • Machine cost calculations	• Required to produce alternative views for South Africa, which are feasible and to determine the most appropriate harvesting systems for each view
9. Configure alternative value chains for pine sawtimber, pine pulpwood and *Eucalyptus* pulpwood plantations and select the most profitable for each	• Brainstorming • Expert judgment • NPV analysis	• Required to formulate industry strategy
10. Formulate a strategy for harvesting systems in South Africa for 2010 that best fits the scenarios described in 7.	• Literature survey • Brainstorming	• To best prepare the industry for the way forward in timber harvesting
11. Forecast the number of machines in the industry for each of the scenarios described in step 7	• Terrain classification • Annual cut forecast	• Machine suppliers can plan for potential market needs and forestry companies can create infrastructure to support machinery.

5.4 The global environmental scanning exercise

5.4.1 The Delphi study

Considering the strong trend towards globalisation and South Africa's position as an importer of harvesting technology, it is essential to establish global trends, which will affect the future South African environment. These trends lie in identifying the change drivers over the next 10 years. The most appropriate method, as discussed in Chapter 4, is the Delphi technique. The application thereof is discussed in more detail below:

5.4.1.1 *The countries included in the sample*

In order to gain the most effective and relevant information possible, countries were selected which will have the greatest influence on South Africa or which will display similar trends to those that can be expected in the South African timber harvesting systems. The factors that contribute to the above are:

- current producers of harvesting technology (machinery and equipment);
- potential future producers of harvesting technology; and
- countries that have expanded, or are currently expanding their plantation forestry areas.

Table 5.2 gives information on the countries included, as well as prominent machine manufacturer brands in each of these countries.

Table 5.2: Countries included in the Delphi study

Country	Hemisphere	Industrial Annual cut * '000 (m^3)	Prominent machine brands produced
USA	Northern	406 595	John Deere, Timbco, Caterpillar, Prentice, Hydro Ax
Canada	Northern	183 113	Timberjack, Tigercat
Sweden	Northern	52 600	Timberjack, Loglift, Husqvarna
Finland	Northern	42 503	Cranab, Valmet
Germany	Northern	35 543	Stihl
New Zealand	Southern	17 000	Waratah
Australia	Southern	19 813	Rosin
Chile	Southern	21 387	
Total		778 554	

**Source: F.A.O, 1999*

5.4.1.2 *The sample size*

A significant sample of the total global industrial roundwood production was included in the study. Of the 1,49 billion cubic metres of industrial roundwood produced annually, the study included 778 554 000m^3. This is over 52% of the global annual industrial roundwood production. Table 5.3 summarises these results.

Table 5.3: Sample size of Delphi study (FAO, 1999)

Global annual cut* (m^3)	1 489 530 000
Sample annual cut (m^3)	778 554 000
Sample as a percentage of total	52,3%

**Source FAO, (1999)*

5.4.1.3 The profile of panel members

Panel members were carefully selected based on the following criteria:

- International standing in Forest Engineering; and
- specific knowledge of the particular region/country.

Due to the size and complexity of the USA and Canada, these two countries were divided into six and three regions respectively. Each of the other countries were treated as a single entity, with one panel member representing each country, except Chile, which had two panel members, of whom one completed the study. Table 5.4 below summarises the profile of the panel members:

Table 5.4: Profile of panel members

Region/Country	Panel member	Institution
USA: Pacific Northwest	Prof. L. Kellogg	Oregon State University
USA: Inland West Coast	Prof. L. Johnson	University of Idaho
USA: Lake States	Dr. C. Blinn	University of Minnesota
USA: South	Dr. D. Green	University of Georgia
USA: New England	Prof. C. Davis	SUNY
USA: Appalachian region	Dr. R. Visser	Virginia Tech
Canada: West Coast	Mr. A. Sauder	FERIC, Canada
Canada: Central	Prof. R. Pulkki	Lakehead University
Canada: East Coast	Prof. P. Zundell	University of New Brunswick
Sweden	Prof. J. Fryk	Skogsforsk
Finland	Prof. E. Mikkonen	University of Helsinki
Germany	Prof. P. Warkotsch	University of Munich
New Zealand	Dr. G. Murphy	Forest Research
Australia	Mr. S. Shackleton	Timberjack
Chile	Mrs. V. Gonzalez	Universidad Mayor, Santiago

5.4.1.4 The questionnaires

Three rounds of questionnaires were circulated to panel members in the selected countries.

a) The first round questionnaire

The initial questionnaire was drawn up with consideration given to the guidelines of Trochim (1999) with regard to question design. Due to the difficulty in identifying all the relevant criteria, this questionnaire was used to expand the criteria that could be important in the forecast. A combination of closed questions and open-ended questions were thus used. Sixteen panel members participated in the first round, of whom two were from Chile. The questionnaire used and the results of the first round questionnaire are given in Annexure 2.

b) The second round questionnaire

All the additional criteria given by the panel members were included in the second questionnaire. Where possible, the additional criteria were combined, but caution was exercised not to exclude any criteria that would lead to the potential exclusion of important criteria. One additional question was added to determine both the current and the future status regarding the use of contractors for harvesting because one of the panel members from Chile did not return his questionnaire and was excluded from participating in the remainder of the study. The questionnaire used and the results of Questionnaire 2 are given in Annexure 3.

c) The third round questionnaire

The third round questionnaire once again allowed for the consolidation of criteria, based on the type of responses received from the panel members. One additional question was included to determine the future views on the size of contracts. The questionnaire used and the results, as obtained in the third round questionnaire, are given in Annexure 4.

The results of the Delphi study and a discussion of the most important findings follow below.

5.4.1.5 Change drivers over the last decade

Figure 5.1 reflects the change drivers over the last decade. A box plot was completed for each of the criteria listed, the results of which are contained in Annexure 5. It is important to identify the core change drivers over the last 10 years and their relative importance was to have a basis for the future. The respondents were asked to weight the relative importance of the listed factors out of a score of 10.

Figure 5.1 shows that six factors were the primary change drivers over the last 10 years. These are, in order of importance, the following:

- Technological and productivity improvements;
- environmental impacts;
- social pressure;
- labour cost; and
- capital cost
- forest code

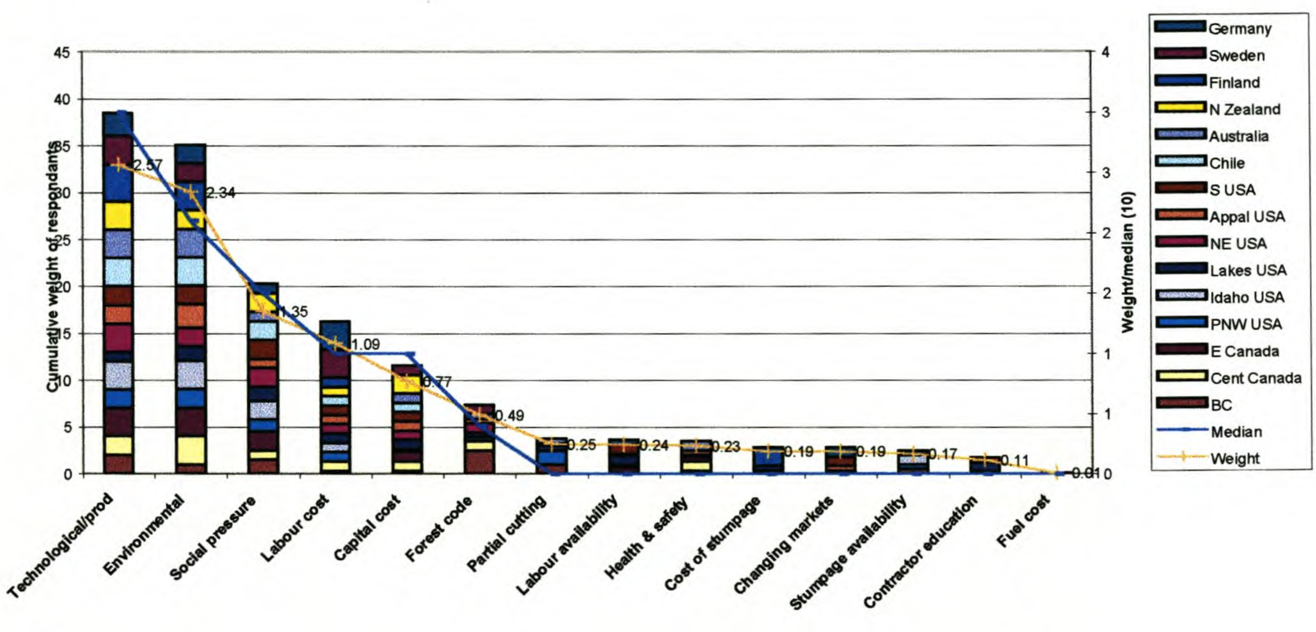


Figure 5.1: Global change drivers – last 10 years

a) Technological and productivity improvements

Technological and productivity improvements were rated as being the greatest contributor to change over the last decade (mean 2,56 and median 3,0). Thirteen of the respondents lie within the box, while one respondent had a higher rating and one respondent had a lower rating (Finland and the Lake States respectively). Both the two outliers are, however, still within the lower 1,5 inter-quartile ranges.

b) Environmental impacts

Thirteen respondents rated environmental impacts between the 25th and 75th percentiles. The two respondents falling outside this range, however, were still within the lower 1,5 inter-quartile range (British Columbia and the Lake States of the USA). There is thus consensus that environmental impacts were the second largest change driver in the last decade (mean 2,34 and median 2,1).

c) Social pressure

Social pressure was ranked the third largest contributor to change (mean 1,35 and median 1,5). Eight of the respondents lie within the 25th to 75th percentiles, while two respondents lie within the 1,5 inter-quartile ranges, who both gave social pressure a zero rating. These are the two Scandinavian countries: Sweden and Finland. The reason could be due to the cut-to-length systems prevailing in these two countries, which are generally viewed as environmentally and socially acceptable harvesting systems, and the integrated role that forestry plays within Scandinavian communities.

d) Labour cost

The box plot shows that 10 respondents weighted labour cost the same, while two respondents weighted labour cost higher and three weighted labour cost lower. Both these extremes are outside the 1,5 inter-quartile ranges. The upper extreme values represent Sweden and Germany, whilst two respondents from Canada and the one from Australia weighted the influence of labour cost lower.

e) Capital Cost

Capital cost was weighted 5th. Fourteen of the respondents lie within the 25th and 75th percentiles, while one respondent (New Zealand) weighted it higher, but still within the 1,5 inter-quartile range.

f) The implementation of Forest Practice codes

Forest practice codes was ranked 6th. Only British Columbia weighted forest practice codes significantly higher (2,5 out of 10). The remainder of the respondents were all within the 25th and 75th percentiles with a mean of 0,49 and a median of 0.

g) Other

The following change drivers were ranked as less important or unimportant over the last decade, with all having a median of 0:

Partial cutting	(7)
Labour availability	(8)
Health and safety	(9)
Cost of stumpage	(10)
Changing markets	(11)
Stumpage availability	(12)
Contractor education	(13)
Fuel cost	(14)

In summary, two drivers dominated change (technological/productivity improvements and environmental impacts); four drivers made a significant contribution, and eight drivers were relatively insignificant.

5.4.1.6 Change drivers over the next decade

Figure 5.2 reflects the change drivers expected to influence harvesting systems over the next decade. A box plot has been completed for each of the criteria listed, the results of which are contained in Annexure 6. Respondents were once again asked to weight the relevant potential change drivers, the reason for this approach being the same as discussed in paragraph 5.4.1.5.

Two prominent change drivers emerged for the next decade (Figure 5.2):

- environmental impacts; and
- technological and productivity improvements.

Although both these factors were also identified as the major change drivers over the last decade, it is important to note that environmental impacts is now the greatest change driver. Other factors of importance are:

- social pressure;
- capital cost;

- labour cost; and
- global competition.

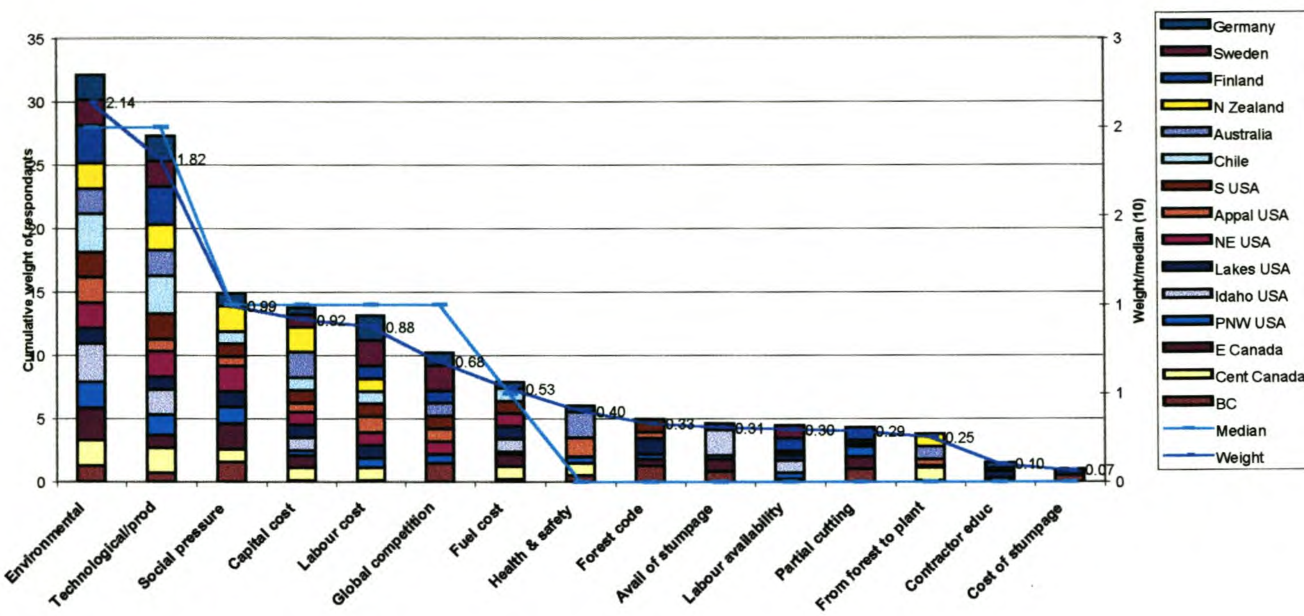


Figure 5.2: Global change drivers – next decade

a) Environmental pressures

Environmental pressures was ranked as the most important change driver in the next decade (Figure 5.2), with a mean of 2,1 and a median of 2. Ten respondents lie between the 25th and 75th percentiles, while Eastern Canada, the Inland Empire of the USA and Finland rated this factor higher than the remainder. The Lake States of the USA and British Columbia believes this factor will be of less significance, but both responses are still within the 1,5 inter-quartile range.

b) Technological and productivity improvements

After environmental pressures, technological and productivity improvements are viewed as the most important change driver in the next decade, with a mean of 1,82 and a median of 2. Chile and Finland believe this to be more important than the remainder, while British Columbia rates it lower than the remainder. All respondents lie within the 1,5 inter-quartile ranges. Twelve respondents lie within the box, thus indicating consensus.

c) Social pressure

Social pressure is ranked 3rd, with a mean of 0,99 and a median of one. Three regions/countries, namely Eastern Canada, North East USA and New Zealand, weighted social pressure above the box but still within the 1,5 inter-quartile range. The remaining 12 respondents lie within the box, indicating consensus on this issue.

d) Capital cost

The cost of capital is ranked 4th, with a mean of 0,92 and a median one. Ten of the respondents lie within the 25th and 75th percentile points, whilst Australia and New Zealand rated it significantly higher (2). Three countries ranked the cost of capital within a distance of 1,5 below the inter-quartile ranges, but outside the box .

There is thus not consensus regarding weighting of the cost of capital. Most significantly, Australia and New Zealand's results deviate significantly from the remainder of the respondents. The reason could be the strong devaluation of these currencies since the economic meltdown in Asia in 1998.

e) Labour cost

Labour cost is ranked 5th, with a mean of 0,88 and a median of 1,0. Only two respondents believed labour cost to be more important than those lying between the 25th and 75th percentiles; Germany and the Appalachian Region of the USA.

f) Global competition

Global competition is weighted as the 6th most important change driver. Thirteen of the respondents lie within the inter-quartile range. No respondent lies outside a distance of 1,5 times the inter-quartile ranges. There is thus consensus on the weighting of global competition.

g) Fuel cost

The cost of fuel was ranked 7th (mean 0,53 and median 0,5). The values of respondents lie between the 25th and 75th percentiles. The cost of fuel therefore remains a factor contributing to change in harvesting systems over the next decade.

h) Other factors

Other factors identified as change drivers were ranked as follows:

Health and safety	(8)
Forest practice code	(9)
Availability of stumpage	(10)
Availability of labour	(11)
Partial cutting	(12)
From forest to processing plant	(13)
Contractor education	(14)
Cost of stumpage	(15)

These factors are far less significant, with all of them having a median of 0.

From the results, one can assume that environmentally sound harvesting will become more important over the next 10 years, that technological breakthroughs will continue to increase productivity and that both the cost of labour and machines will continue to increase globally. However, increased global competition, particularly emanating from Australia, and technological breakthroughs will assist in competitive pricing and superior features on machines.

5.4.1.7 Changes in harvesting systems in 2010

Figure 5.3 gives the ranking of the changes that are expected to have taken place by the year 2010. Where questions 1 and 2 used a weighting, the respondents were asked to rank the factors in this question. The reason for this was that opposed to only identifying the core change drivers, this question required a response to all factors listed as potential changes in harvesting systems in 2010. This could only be achieved by using a ranking system. Note that 1 is the highest ranking and 20 the lowest. Annexure 7 contains the box plot results for each factor.

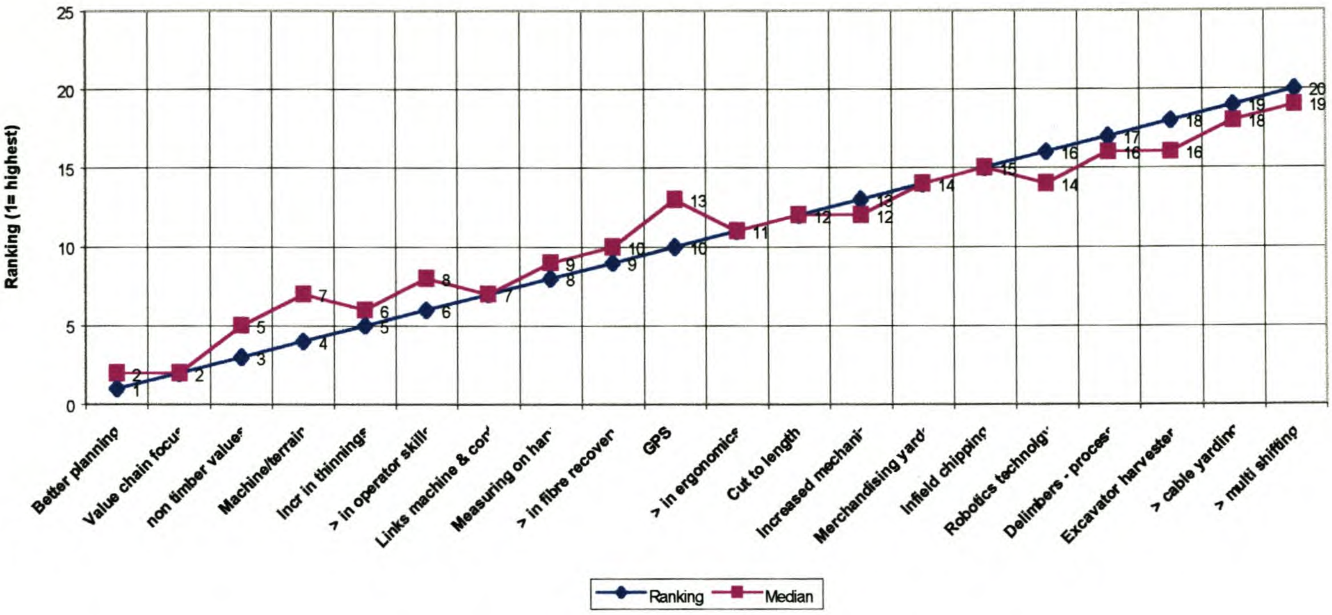


Figure 5.3: *Changes in harvesting systems in 2010*

The most important changes that are expected to take place in harvesting by 2010, in order of importance, are:

- Better harvesting planning.
- A focus on the overall value chain in logging operations.
- A focus on non-timber values in harvesting operations (aesthetics, biodiversity).
- Machines will be more versatile with regard to terrain conditions.
- There will be an increase in thinning operations in lieu of clearfelling.
- Operators will have to be more skilled to work the machines of the future.
- Computers will be used to assist with timber flow and cutting patterns.

a) *Better planning of harvesting operations*

Better harvest planning was ranked as the most important change in harvesting with a mean of 2,36 and a median of 2. Sweden was the only exception, being ranked 9th out of 20 criteria, possibly due to the advanced levels of planning already prevalent in this country. Thirteen of the respondents lie between the 25th and 75th percentiles.

b) A focus on the whole value chain

There was consensus on the ranking of this as the second most important change in harvesting operations in 2010. Five respondents ranked it first and seven ranked it second. The only exception was the Lake States of the USA, where it was ranked last. The reason for this is unsure. The mean ranking is three and the median two.

c) Non-timber values

Non-timber values corresponds with the social pressure and environmental impact change drivers, both of which were rated as being very important. Similarly, the inclusion of non-timber values was ranked 3rd out of 20. Although no ranking was higher than 10, ten respondents lie within the box and all respondents fall within the 1,5 inter-quartile ranges. There is thus fair consensus on the ranking of non-timber values.

d) Machine / terrain interaction

This factor relates to more versatile mechanised systems being developed with regard to terrain conditions (i.e. slope, soil conditions, ground roughness) and was ranked 4th. All respondents ranked it 11th or lower, with nine lying within the box, reflecting fair consensus with regard to this factor.

e) Increase in thinnings / partial cutting

Nine of the respondents lie within the inter-quartile ranges. The ranking for this factor was 5th. However, it was ranked 19th for New Zealand, indicating that not all respondents believe that thinnings will replace clearcutting in the future, particularly in those countries dominated by plantation forestry. Its ranking of 5th place does, however, indicate there will be a trend towards partial cutting over the next decade.

f) Increase in operator skills

Due to the development of more sophisticated machinery, it can be expected that operator skills will have to increase for machines used in harvesting operations in 2010. This factor was ranked 6th. Australia, the Appalachian region of the USA and Sweden ranked it lower than the other countries, but 12 of the 15 respondents lie within the inter-quartile ranges, thus reflecting consensus.

g) Links between machine and control room

This factor was ranked 7th, with eight responses lying within the inter-quartile ranges. Central Canada (18), the Lake States of the USA (18) and the Southern USA (17) ranked this factor lower.

h) More accurate measuring on harvesters

The results indicate that new technology will improve measuring accuracy on harvesters, and was ranked 8th.

i) Fibre recovery

An increase in fibre recovery was ranked 9th. Ten of the 15 respondents lie within the inter-quartile ranges, indicating a fair consensus. Three countries ranked it lower, namely Chile, the Appalachian region of the USA and New Zealand.

j) GPS

GPS, ranked 10th, have nine respondents lying within the box and all respondents within the 1,5 inter-quartile ranges. The use of GPS technology in harvesting machines will be common practice in 2010.

k) Increase in ergonomics

The increase in ergonomics on harvesting machines was ranked 11th. The exception is Finland, where it was ranked last. Scandinavian machines are generally already ergonomically superior, and these countries are probably of the view that ergonomics will only show incremental improvements over the next decade. The ranking of 11th does indicate that machines built to meet the ergonomic standards set in Scandinavia, will improve significantly by 2010.

l) Increase in cut-to-length systems

This factor was ranked 12th out of 20. Australia, Canada and USA generally ranked it high, while countries where this system is already well established ranked it low. There is a divergence of opinion as 12 of the 15 respondents fell within the inter-quartile range. This can be expected, considering the various geographic regions of the world from which the respondents came. Of importance is the fact that an increase in cut-to-length systems can be expected in regions, which are currently dominated by tree-length systems.

m) Increase in mechanisation

Increase in mechanisation was ranked 13^{th}. Exceptions are New Zealand (ranked $3^{rd)}$ and the Appalachian region of the USA (ranked 5^{th}). Most of the countries represented in the study are already highly mechanised, hence the relatively low ranking of this factor.

n) Value recovery through processing yards

This factor was ranked 14^{th}. Three countries considered it more important, namely, Chile (8^{th}), the Appalachian region of the USA (7^{th}) and the Pacific Northwest of the USA (4^{th}).

o) Infield chipping

Infield chipping was ranked 15^{th}, with 13 of the respondents lying within the box. The only country receiving a high ranking was Australia, where it was ranked 4^{th}.

p) The use of robotics technology

There was consensus that robotics technology in harvesting equipment has a relatively low ranking. Although many researchers believe that robotics will substitute most of the repetitive operator functions, the results of this study indicate that only marginal progress will be made by 2010.

q) Sophistication levels of delimbers

The importance of stroke boom delimbers also extracting grade material in future was ranked low (17^{th}). No country gave this factor a high ranking.

r) Use of excavator base carriers for harvesters

An increase in the use of excavator base carriers for harvester heads was ranked 18^{th}. Only nine of the fifteen respondents fall within the inter-quartile range, reflecting a divergence of opinion. It was ranked 5^{th} for Australia, and ranked last and second last by Finland and Germany respectively.

s) An increase in cable yarding

It is important to note that cable yarding, although ranked 19th, was ranked first by New Zealand and second by the Appalachian region of the USA. There is thus not consensus on this factor, indicating that some panel members believe that cable yarding will replace ground-based systems in the future. This is primarily influenced by the prevailing terrain conditions in various regions of the world, and how these will change over the next decade, as the sites being harvested change.

t) Multi-shifting of harvesting machines

Multi-shifting was ranked last by the panel. The exception was the Lake States of the USA, where it was ranked 3rd. Considering the high importance of the cost of capital as a change driver, it would have been expected that multi-shifting would in future be used to negate the high cost of capital. However, there is consensus amongst most panel members that multi-shifting will not increase significantly by 2010, compared to current levels of utilization.

5.4.1.8 Outsourcing of harvesting operations

Questions 8 and 9 of the study focused on future patterns regarding the outsourcing of harvesting operations. Question 8 focused on the percentiles of volume outsourced by forestry companies, while Question 9 focused on the size of the future contracts.

Figure 5.4 shows that 84% of current harvesting operations included in the study are outsourced. This figure is expected to increase to 90% by the year 2010. This question only passed through two rounds of the Delphi study. All respondents agreed that outsourcing will increase in future.

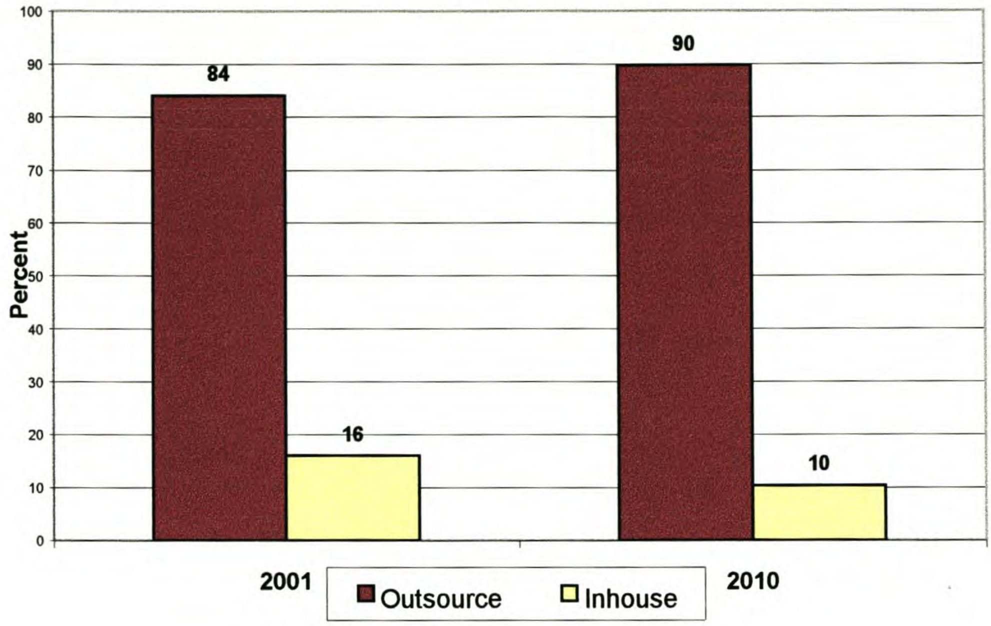


Figure 5.4: Outsourcing vs. In-house 2001 vs. 2010.

The question on annual contracts was only included in the last round and these results are therefore only indicative of possible trends. Figure 5.5 reflects the size of the annual contracts put out to contractors for ground based harvesting. The answers reflect how companies view the size of the contracts that they are working with at present and how this is expected to change in 2010. Due to the lack of information for their region/country, five of the 15 respondents were not willing to answer this question. The results indicate that contract sizes will increase by 2010. Only 33% of annual contracts are expected to be less than 50 000m³ per year, as opposed to the current 44%. This trend is also reflected in the 100-200 000m³ and 200-500 000m³ contract sizes, where the figures are 16% in 2001, as opposed to 21% in 2010 and 10% in 2001, as opposed to 13% in 2010 respectively.

From the results it can be concluded that, not only will the outsourcing of harvesting operations increase, but also the size of annual contracts.

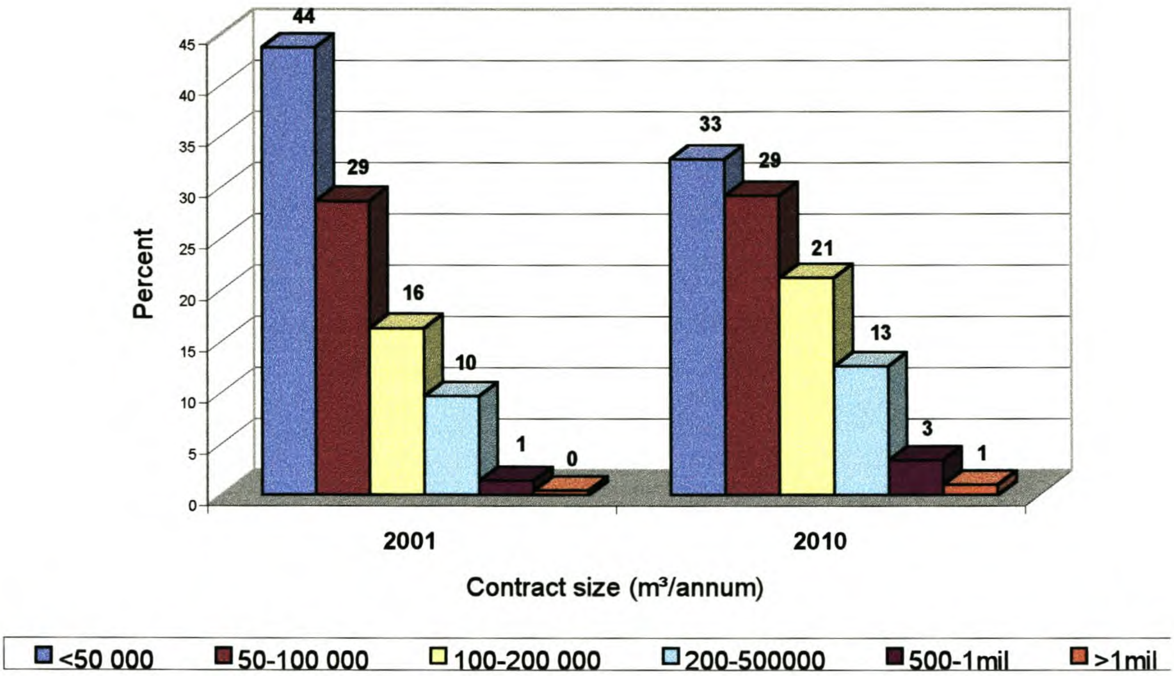


Figure 5.5: *Contract sizes*

5.4.1.9 Future requirements of harvesting foresters and contractors

The Delphi study included 2 questions regarding the future requirements of harvesting foresters and contractors. Panel members were asked to rank the most important requirements of a harvesting forester and harvesting contractor in 2010. The box plots for each of the criteria are given in Annexure 8. Figures 5.6 and 5.7 show the results of the respondents. A ranking system was once again used for these two questions. The ranking forced the respondents to give a value to each factor, thereby avoiding the probability of some factors being totally ignored/discredited, which could be important in the education and training of harvesting persons.

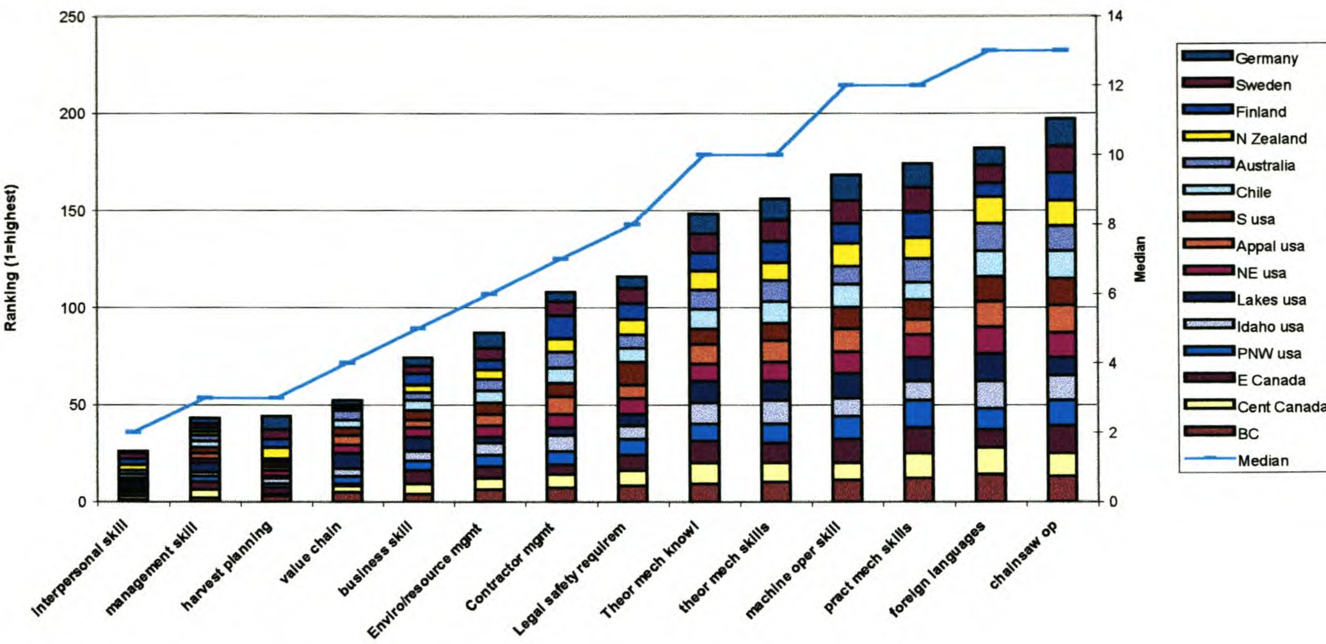


Figure 5.6: *Skill requirements of a harvesting forester in 2010*

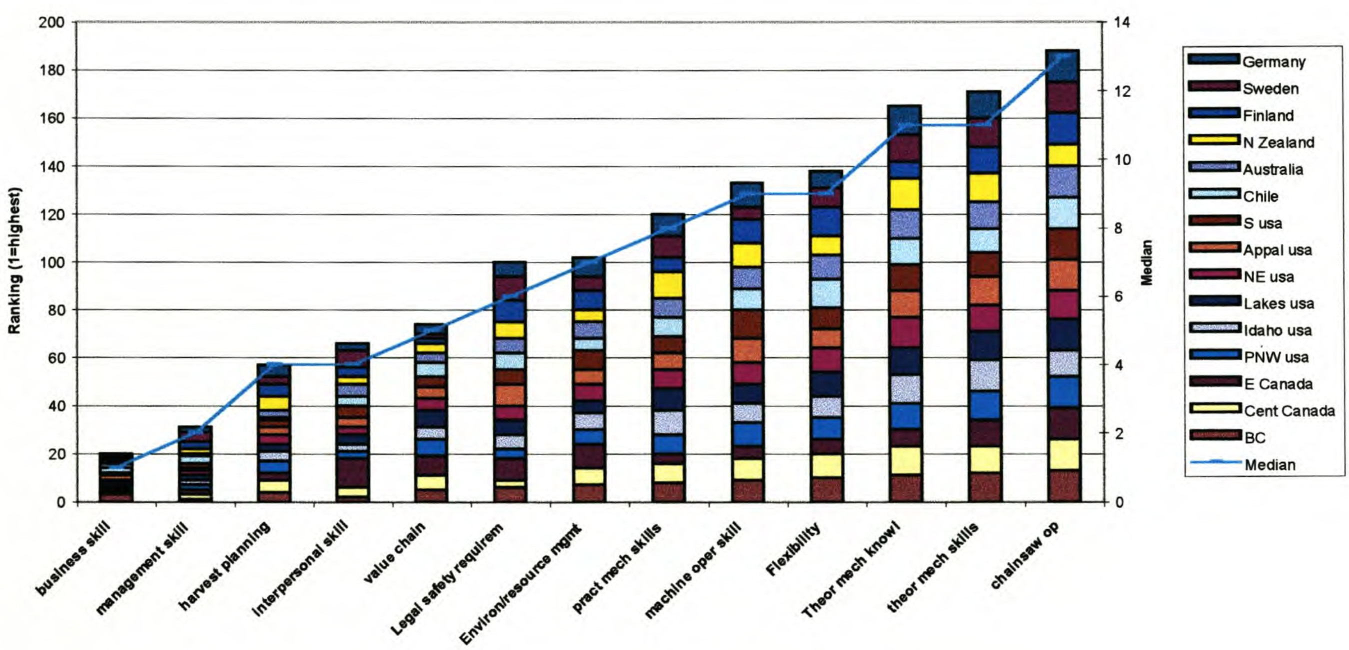


Figure 5.7: *Skill requirements of a harvesting contractor in 2010*

The results indicate that the most important skill requirements for a harvesting forester in 2010 are, in order of priority:

- inter-personal skills;
- management skills;
- harvest planning;
- an understanding of the full value chain of Forest Engineering;
- business skills;
- environmental and resource management skills; and
- contractor management.

Likewise, contractors will be expected to have the following skills:

- business skills;
- management skills;
- harvest planning;
- inter-personal skills;
- an understanding of the full value chain of Forest Engineering;
- legal and safety knowledge; and
- environmental and resource management skills.

a) Inter-personal skills

Inter-personal skills were rated as the most important requirement for a harvesting forester and ranked 4th with regard to a harvesting contractor for a harvesting forester, 12 of the 15 respondents lie in the inter-quartile ranges, with the highest ranking by any respondent being 3rd. This supports the high level of consensus amongst respondents as this being the number one requirement. Interestingly, as with business skills and management skills, this is not a forestry-related subject, and hence not required to be taught at forestry faculties.

However, it could be quite simple to modify existing curricula to enhance the inter-personal skills of students. This can be done through the following ways:

- Allow for as much group work as possible.
- Regularly mix groups around so that students learn to work with different people.
- Allow free debating of subject matter in class.

- Have students regularly present their work to the remainder of the class, thereby teaching them presentation skills in the process.

b) Business skills

This refers to an understanding of strategic management, financial management, marketing, risk assessment, the use of e-business and personal stress management.

Business skills is the only requirement where there is a significant deviation from the ranking of the panel members for a harvesting forester (5^{th}) and a harvesting contractor (1^{st}). Business skills are relatively important for a harvesting forester, but are seen as the most important attribute for a harvesting contractor to possess.

The debate on the relevance of business courses in a curriculum is not unique to forestry, e.g. the engineering, accounting, agricultural and legal professionals face the same questions. However, there is a danger that due to the emphasis placed on these courses, they could in future substitute the technical forestry courses. This situation is to be avoided, as a forestry course remains, in essence, a forestry curriculum.

As with management and interpersonal skills, lecturers should search for methods of conveying the teaching of sound business principles through their traditional forestry subjects. An example would be to work business principles into the core subjects of harvest planning, such as:

- The process of resource allocation is already part of harvest planning.
- Strategic, tactical (3-5 year) and operational planning.
- The annual budgeting for a harvesting operation.
- The day-to-day planning and control required in a harvesting operation.

c) Management Skills

This refers to the traditional management roles of planning, leading, organising and controlling. It also includes labour relations. This factor was ranked as the 2^{nd} most important requirement for both harvesting foresters and contractors.

Although management skills have been so highly rated, it is as with the first two factors strictly speaking not a forestry related subject. The high rating suggests that management skills should also be considered in forestry curricula through the courses being offered. Students can be taught management skills through the approach used by lecturers to convey technical subject matter, as discussed previously.

d) Harvest planning

The ability of both harvesting foresters and contractors to plan harvesting operations was ranked 3rd.There is strong consensus regarding the ranking with 11 and 13 of the respondents lying within the inter-quartile ranges for a harvesting forester and a harvesting contractor respectively.

Harvest planning thus needs to constitute a major portion of the Forest Engineering curriculum at tertiary educational institutions teaching forestry.

e) Value chain knowledge

Harvesting systems and value chain knowledge refers to the ability to assess machines for a particular application, the configuring of machines to optimise the value chain and the ability to cost out a system. This requirement was ranked 4th for harvesting foresters and 5th for harvesting contractors. There was also consensus regarding this requirement, with 14 and 10 respondents lying in the inter-quartile ranges for harvesting foresters and contractors respectively. This should thus form the core subject in tertiary harvesting education courses.

f) Environmental and resource management skills

The need to understand environmental and natural resource issues was ranked 6th for a harvesting forester and 7th for a harvesting contractor. There is strong consensus on the ranking from panel members (11 panel members ranked this factor at 6 for a harvesting forester and 7 for a harvesting contractor).

This ranking is high enough to, not only include its teaching in all Forest Engineering subjects, but also to include it as a stand alone minor subject in the Forest Engineering curriculum.

g) Contractor management

This factor is obviously only relevant to the requirements of a harvesting forester and was ranked 7th. There wasn't consensus regarding this ranking.

h) Legal safety requirements

This requirement was ranked 8th for a harvesting forester and 6th for a harvesting contractor. Safety issues have been a very prominent factor in harvesting operations over the last decade, and the consensus of respondents is that it will remain relatively important over the next decade. Twelve respondents lie within the inter-quartile ranges for a harvesting forester and also for a harvesting contractor.

i) Theoretical mechanical knowledge

Theoretical mechanical knowledge refers to the theory of the internal combustion engine, the drive train and the electrical systems applicable to harvesting machines.

There is consensus amongst the panel members on the ranking of this requirement (9th out of 14) for a harvesting forester and 11th out of 13 for a harvesting contractor. It is thus clear that this should not be a major portion of the tertiary education curriculum, but it should be included to the extent that students are given a sound understanding of the functioning of a machine.

j) Theoretical mechanical skills

This factor refers to an understanding of the requirements for repairing and servicing of a machine. It was ranked 10th for a harvesting forester and 12th for a harvesting contractor. As with theoretical mechanical knowledge, the theory of repairs and maintenance needs to be taught to students, but at a relatively superficial level.

k) Machine operator skills

This refers to the ability to physically operate a machine. This factor was ranked 11th for a harvesting forester and 9th for a harvesting contractor, indicating a relatively low level of importance. Ten of the 15 respondents lie in the inter-quartile ranges for a harvesting forester and 12 for a harvesting contractor.

l) Practical mechanical skills

This factor refers to the ability to repair and service a machine. It was ranked 12th for a harvesting forester and 9th for a harvesting contractor. This factor is thus relatively unimportant.

m) Foreign languages

A foreign language was only seen as a requirement for a harvesting forester and not for a contractor. It was ranked 13th out of 14 factors and is thus not deemed important with regard to tertiary forestry education. This factor, however, is a broader societal issue related of the demographics of each particular region or country.

n) Chainsaw operator skills

This requirement was ranked last for both harvesting foresters and contractors, indicating the progressive redundancy of chainsaws, as the technology of alternative systems continues to improve.

o) Flexibility

The issue of flexibility of equipment was only applicable to harvesting contractors and was ranked 10th.

Although most tertiary educational courses in harvesting in developed countries should seriously consider the inclusion of any course work on chainsaws, it still remains an important piece of equipment in South Africa.

Tertiary institutions, both nationally and abroad will need to include the factors discussed as part of their core Forest Engineering and/or harvesting programmes. It is important to note that business skills, management skills, inter-personal skills and contractor management skills can be taught through traditional Forest Engineering subjects. The same material can be used, but must be conveyed to students in another format, to meet the above requirements. Adult learning and continuing education programmes have become an increasingly important mechanism to fulfil the demands for new skills. Employers of new graduates may need to provide pre-service training programmes on specific subjects not covered by their formal training.

There is also a growing reliance on continuing education or in-service training to give mid-career personnel new knowledge and skills.

5.4.2 Machine substitution curves

The development of Fisher-Pry substitution forecasts, as discussed in Chapter 4, were used to determine the rate and degree of substitution of one type of machine by another. The main driving force behind substitution is the reduced environmental impact of cut-to-length systems as opposed to tree-length systems. Similarly, swing boom carriers for feller bunchers are softer on the soil than drive-to-tree carriers. The estimated machine sales, which form the basis for the forecast, were obtained from Shackleton (2000). Table 5.5 gives the figures for various machines over a 10-year period.

Table 5.5: Estimated machine sales (units) over the last 10 years (Shackleton, 2000)

Year	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Harvesters, rubber wheeled	548	700	573	333	335	417	590	738	589	790	842	828
Harvesters track, purpose-built	3	5	42	52	103	166	195	236	83	127	142	172
Harvesters, excavator-based	220	245	225	220	341	440	530	505	285	211	273	270
Harvesters total	**771**	**950**	**840**	**605**	**779**	**1023**	**1315**	**1479**	**957**	**1128**	**1257**	**1270**
Feller bunchers, STT	426	422	316	209	285	393	498	591	474	469	461	417
Feller bunchers, DTT	860	711	779	746	979	1088	1140	1105	973	978	891	516
Feller bunchers total	**1286**	**1133**	**1095**	**955**	**1264**	**1481**	**1638**	**1696**	**1447**	**1447**	**1352**	**933**
HARVESTING TOTAL	**2057**	**2083**	**1935**	**1560**	**2043**	**2504**	**2953**	**3175**	**2404**	**2575**	**2609**	**2203**
Forwarders	1307	1188	976	596	552	655	894	1290	1049	1212	1358	1343
Skidders	4067	3578	2927	2243	2367	3149	3442	3858	2882	3249	3153	2153
Track Skidders	845	870	480	275	595	730	765	820	790	652	344	576
TRANSPORTING TOTAL	**6219**	**5636**	**4383**	**3114**	**3514**	**4534**	**5101**	**5968**	**4721**	**5113**	**4855**	**4072**
Log loaders, trailer mounted	1256	1133	927	577	834	1100	1626	1606	1162	1231	1409	913
Log loaders, track mounted	688	636	477	266	382	815	855	855	839	813	658	617
LOADING TOTAL	**1944**	**1769**	**1404**	**843**	**1216**	**1915**	**2481**	**2461**	**2001**	**2044**	**2067**	**1530**
ALL TOTAL	**10220**	**9488**	**7722**	**5517**	**6773**	**8953**	**10535**	**11604**	**9126**	**9732**	**9531**	**7805**

The results of the Delphi analysis illustrate how the social and political awareness of environmental impacts have been an important change driver over the last decade and will become the most important driver in the next decade. It is expected that tree-length harvesting (TL) and drive-to-tree (DTT) technology will come under more pressure in the future and that the environmentally friendly systems will gain market share. The following machines were analysed:

- Skidder *vs.* forwarder
- Feller buncher *vs.* harvester
- DTT feller buncher *vs.* STT feller buncher

The results of the forecast are given below:

Annexure 9 contains the Fisher-Pry regression results. Figure 5.8 shows that forwarders will continue to substitute skidders. Forwarders currently have 35% of the market share. The forecast indicates that this figure will be 72% by 2010.

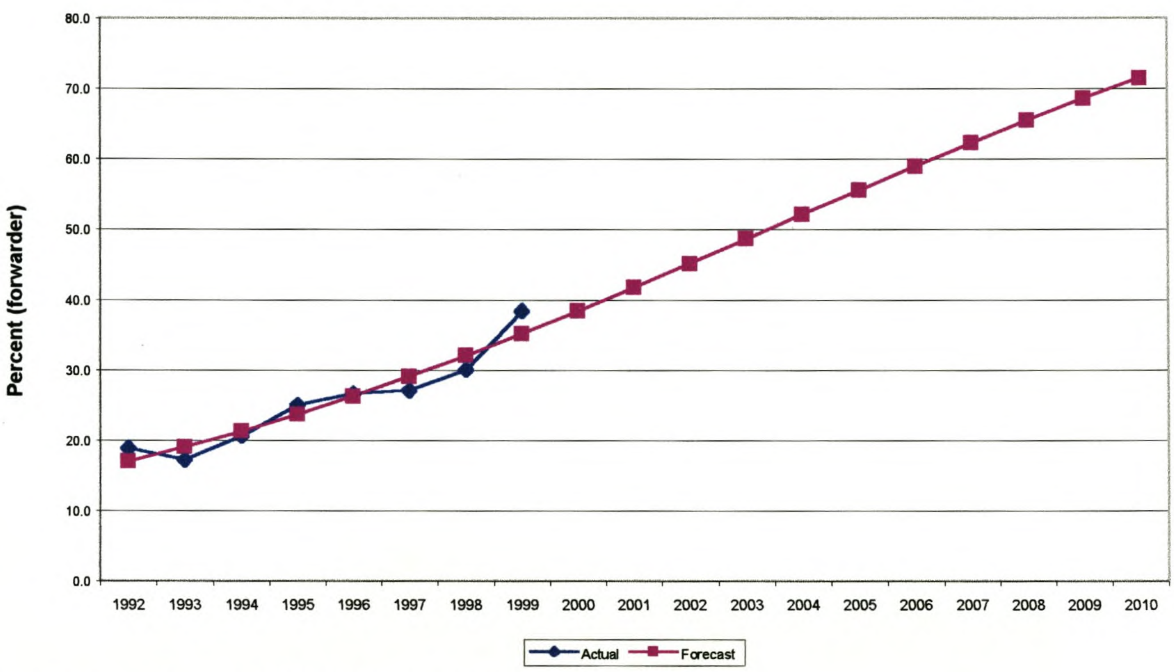


Figure 5.8: Forwarder vs. skidder substitution trend

The market share of STT feller bunchers will increase from 42% in 2001 to 60% in 2010 (Figure 5.9). DTT machines will therefore continue to become less popular over time.

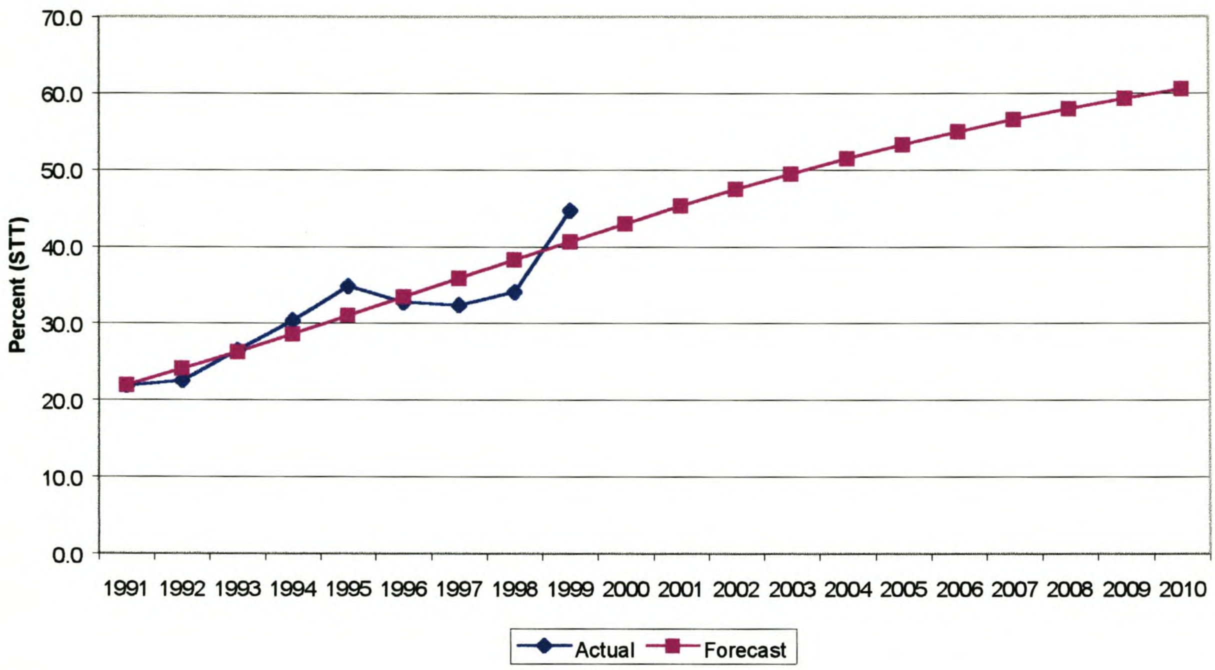


Figure 5.9: Swing-to-tree vs. drive-to-tree feller buncher substitution trend

Harvesters will replace feller bunchers over time. The market share of harvesters will increase from 54% in 2001 to 72% in 2010 (Figure 5.10).

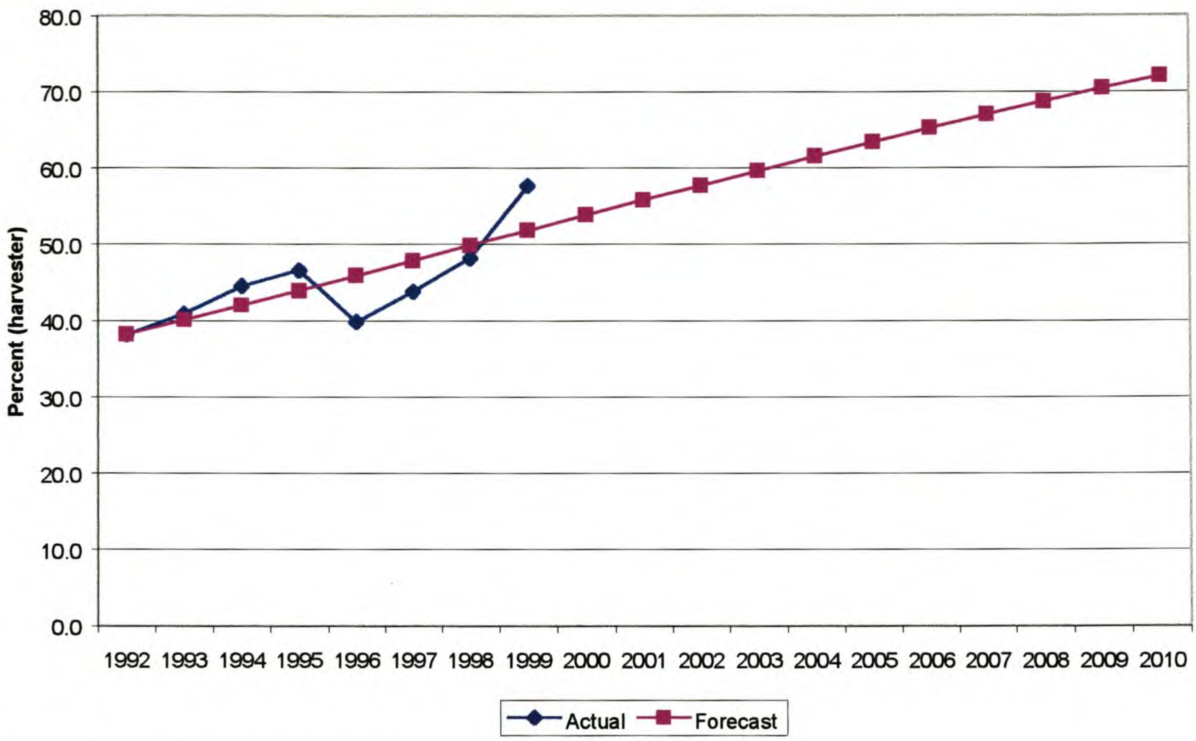


Figure 5.10: Harvester vs. feller buncher substitution trend

Although the results of the Fisher-Pry analysis are not discrete, the study does indicate a trend of substitution of machines, as reflected in the figures above. The importance of the results lies in two areas:

- Harvesters, forwarders and STT machines will continue to substitute feller bunchers, skidders and DTT machines. The magnitude of the substitution is not certain, due to the absence of sufficient past data points.
- Feller bunchers, skidders and DTT machines cannot be expected to have been discontinued by 2010.

The substitution trends are a direct result of the influence of environmental and social pressure change drivers over the last 10 years. When considering that these change drivers are expected to increase in importance over the next decade, then the substitution trends indicated above should be interpreted as being conservative. In any event, it can be expected that the machines being substituted would still be manufactured by the global forest machine suppliers and therefore be available as an option for South African forestry operations.

5.4.3 The relevance of global change drivers to South Africa

Table 5.6 lists the key driving forces for the next decade, as identified in the Delphi analysis and identifies the relevance of each particular change driver to South Africa. The relevance to South Africa is based on the current issues facing the industry.

Table 5.6: Present and future key change drivers and their relevance to South Africa

Primary driving forces		**Relevance to South Africa***
Political	Implementation of forest practices, codes and certification	1
Economic	Increased fuel cost Increased cost of capital (more expensive machines)	1
Social	Social pressure, forcing harvesting operations to become more socially acceptable Increased labour cost	2
Technical	Increased technological performance of machines, leading to higher productivity and less environmental impact	1
Environmental	Higher awareness of the environmental impact of machines	1
Secondary driving forces		
Social	Health and safety issues of workers	2
Economic	Global competition Availability of labour	1 1
Environmental	Availability of stumpage	3

*Note: 1 = high relevance
2 = moderate relevance
3 = not relevant

5.5 The South African environmental scanning exercise

5.5.1 A SWOT analysis of the South African Forest Engineering environment

To place the international change drivers into the South African context and to identify change drivers unique to South Africa, a SWOT analysis of South African harvesting operations is used, as shown in Figure 5.11. The SWOT analysis was compiled by an individually - based brainstorming exercise conducted by the author.

Strengths	**Weaknesses**
Availability of labour Cost of fuel Certification	Lack of work ethic Crime and violence Political role of unions HIV/AIDS
Opportunities	**Threats**
Increased performance of machines – higher productivity Certification Global competition Increased fuel efficiency of machines	Globalisation of machine market Environmental impacts Social pressure (international) Increased cost of capital Increased labour costs Increased fuel costs Health and safety of workers Certification AIDS

Figure 5.11: SWOT analysis of change drivers for South African timber harvesting

The Forest Technical Survey (FTS), described in Chapter 2, gives an in-depth overview of the *status quo* of timber harvesting and transport in South Africa. The comparison of the 1997 FTS results with those of 1987 indicates some of the trends in South Africa over the past decade. Two important results of the comparison given in Chapter 2 are:

- the increase in mechanisation in harvesting operations; and
- the increase in the use of contractors.

5.5.2 A PESTE analysis of the South African Forest Engineering environment

The environmental scanning exercise is conducted by using the PESTE approach, therefore using the following headings:

- Political forces.
- Economic forces.
- Social forces.
- Technological forces.
- Environmental forces.

5.5.2.1 Political forces

a) Competitiveness of South Africa

Buys (2000) defined international competitiveness as "the ability of a nation to produce goods and services that meet the test of international competition, while providing sustained increases in the standard of living for its citizens". Although this definition cuts across the full spectrum of the PESTE analysis of a country, it is being addressed under the heading "political", as Government is seen to have the greatest influence on creating the appropriate climate to increase competitiveness. The International Institute for Management Development (IMD) in Switzerland compiles an annual rating of some 47 countries with regard to competitiveness. The 47 largest economies in the world have been selected for evaluation, with South Africa being the only African country represented in the survey. South Africa's position has continually improved since 1996, when it was ranked 44th, to its 38th position in 2000 (IMD, 2001). When including only the countries with large forestry industries, then South Africa is ranked 22nd out of 26 countries. Table 5.7 gives a summary of South Africa's ranking in various categories.

Table 5.7: South Africa's competitiveness ranking for 2000 (IMD, 2001)

World competitiveness rating: 38 out of 47			
Domestic economy	36	**Infrastructure**	33
Value added	35	Basic	22
Investments	41	Technological	36
Savings	38	Business	36
Final consumption	35	Health	32
Cost of living	1	Energy	30
Adaptiveness	37	Environmental	39
Internationalisation	44	**Management**	28
Current account	28	Productivity	18
Exports	35	Labour costs	13
Imports	34	Corporate performance	33
Exchange rate	33	Management efficiency	43
Portfolio investments	20	Corporate culture	31
Foreign investments	43		
Protectionism	41		
Openness	46		
Government	24	**Science and Technology**	45
National debt	31	R & D expenditure	34
Government expenditure	37	R & D personnel	47
Fiscal policies	14	Technical management	28
State efficiency	9	Scientific environment	44
Justice & security	33	Intellectual property	35
Finance	33	**People**	47
Cost of capital	42	Population characteristics	47
Availability of capital	30	Labour force characteristics	43
Stock market dynamics	25	Employment	47
Banking sector efficiency	35	Unemployment	46
		Educational structures	45
		Quality of life	39
		Attitudes and values	47

Some of the strengths (where South Africa was ranked either 1^{st}, 2^{nd} or 3^{rd}), which have a bearing on the Forestry Industry are:

- The cost of electricity (1)
- Overall productivity growth (2)
- Total and current expenditure on education (3)
- Cost-of-living comparisons (1)
- Effective personal income tax rate (1)

The core weaknesses identified in the study, as related to forestry are:

- Personal security (44)
- Labour regulations (46)
- Industrial relations (47)

- Worker motivation (46)
- Science and education (46)
- Educational system (47)
- Unemployment (44)
- Brain drain (47)
- Availability of skilled labour (47)

Although South Africa's ranking has improved from 44th in 1996, to the current 38th position, the relative position of South Africa is poor. It reflects on the investment status of the country. It is important that South Africa continues to improve its position over time, in order to cultivate a strong Forestry Industry. What is important is that the Government's economic policy Gear is strongly supported by important bodies such as the IMF and the World Bank. To improve its ratings, South Africa will have to, amongst other things, become more productive, invest more in education, deregulate the economy further and reduce crime and violence. This in itself will reduce the outflow of skilled people and increase the investment status of the country.

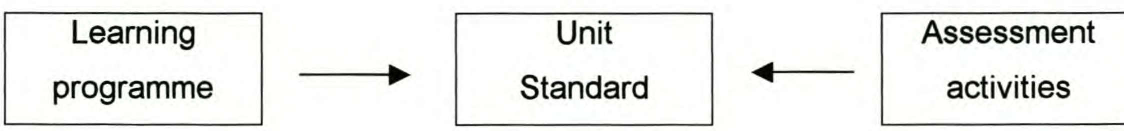
b) New Legislation

Drastic legislative changes have occurred in South Africa during the past decade, with South Africa being one of the countries with the highest number of legislative changes in the world between the period 1994 and 2000. The redrafting of the old Forestry Act (now the National Forests Act), the Basic Conditions of Employment Act and the new Employment Equity Act are examples of legislation that will have huge impacts on forestry and the future route the industry will take (Edwards and Godsmark, 1999). An area of new legislation that needs to be highlighted refers to education and training. The Government promulgated the South African National Qualifications Authority (SAQA) Act in 1995. This Act provides for the development and implementation of a National Qualifications Framework (NQF) onto which all unit standards and qualifications will be registered.

The unit standards required up to, but excluding tertiary education level for Forest Engineering have already been developed by Forest Engineering Southern Africa (FESA) and are in the process of being registered with SAQA (Conradie, 2000).

At the heart of the NQF is the unit standard (us), which states the outcome of learning. It states what a person must know and be able to do in a specific function. This has given the forest industry the opportunity to stipulate their requirements in terms of skills and knowledge required for the various job functions present in the Industry.

Of importance is to note that the us is the outcome. A learning programme is required to achieve the outcome and assessment is required to measure whether the desired outcome has been achieved. One teaches towards the us and assesses against the unit standard, as shown below:



The complete implementation of the SAQA Act by Government is a key certainty. The use of the system by industry is a key controllable. The advantages to industry, by fully implementing the system are:

- the standardisation of training and assessment of the workforce;
- credibility in the training certificates awarded to learners;
- increased productivity and enhanced safety performance; and
- the recouping of training grants from SETA's (Conradie, 2000; Godsmark, 2001).

5.5.2.2 Economic forces

a) Increase in fuel price

Fuel consumption constitutes a significant portion of the costs incurred in the Forest Engineering value chain. There is a correlation between fuel cost and the level of mechanisation. It is therefore important to consider the future cost of fuel when evaluating future harvesting options. With the recent fluctuations in the oil price (Figure 5.12), there has been renewed focus on the impact that fuel efficiency of machines could have on future harvesting systems. When comparing Figures 5.1 and 5.2, it is evident that the cost of fuel played an insignificant role in the last decade, but that it is expected to be a major factor over the next decade.

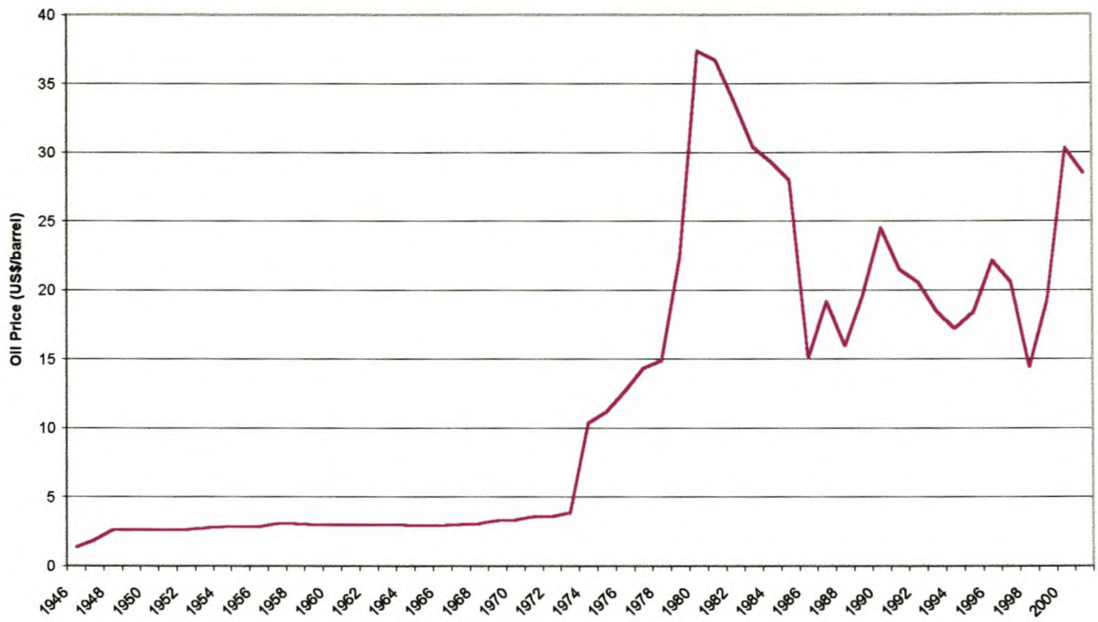


Figure 5.12: International oil price trend (Schussler, 2001)

The impact of high fuel prices on harvesting systems will lead to a focus on methods of saving energy. The Scandinavian CTLM systems are much more focused on low energy consumption per cubic metre produced than what has traditionally been the case with the North American based tree-length harvesting systems (personal observation). This is due to the high taxes on fuel in Western Europe in comparison to those in North America and South Africa.

Figure 5.13 shows the cost of diesel in South Africa over the period 1994 to 2000. There has been a 60% increase in price over the relevant period, indicating that the average annual compound increase amounts to some 7,5%.

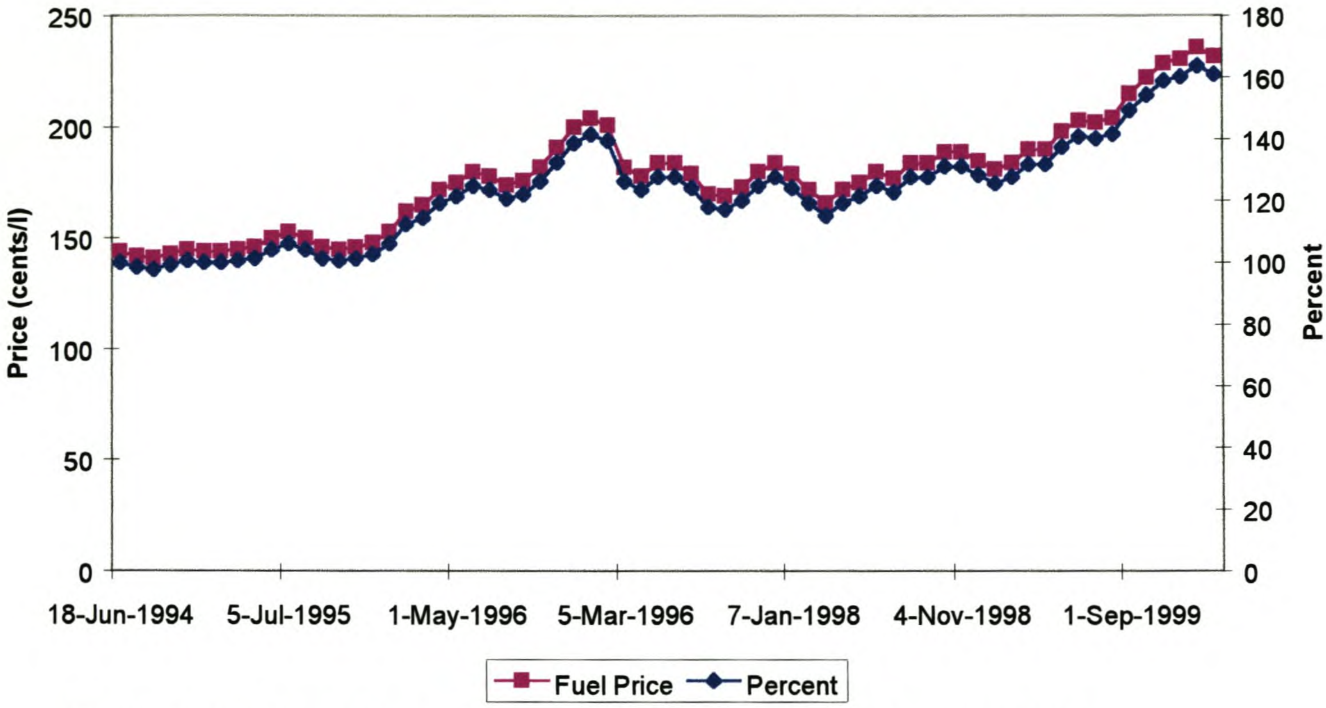


Figure 5.13: Diesel price in South Africa from 1994 to 2000 (Schussler, 2001)

Figure 5.14 compares the current (18 April 2001) South African diesel price with other prominent forestry countries. South Africa's price compares favourably with European countries and is only slightly more expensive than in most of Canada, Australia and the U.S.A. Only Eastern Canada, New Zealand and Chile are significantly cheaper. Tax rebates on diesel in Chile and Eastern Canada make a significant contribution to the low prices (Gonzalez, 2001; Zundell, 2001). The fuel price is regulated in South Africa and it is uncertain whether this would change in future. Another key uncertainty is the future tax and rebate levels of diesel in South Africa.

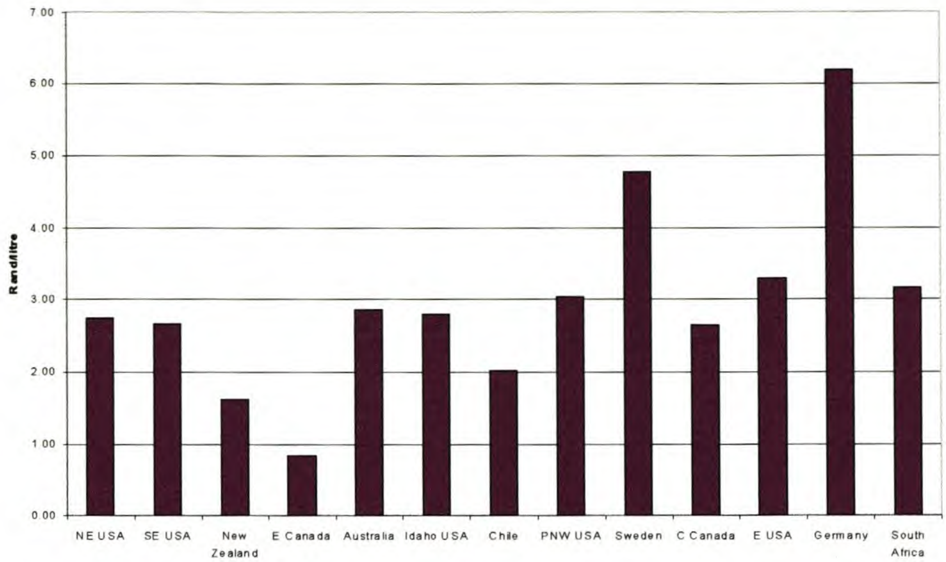


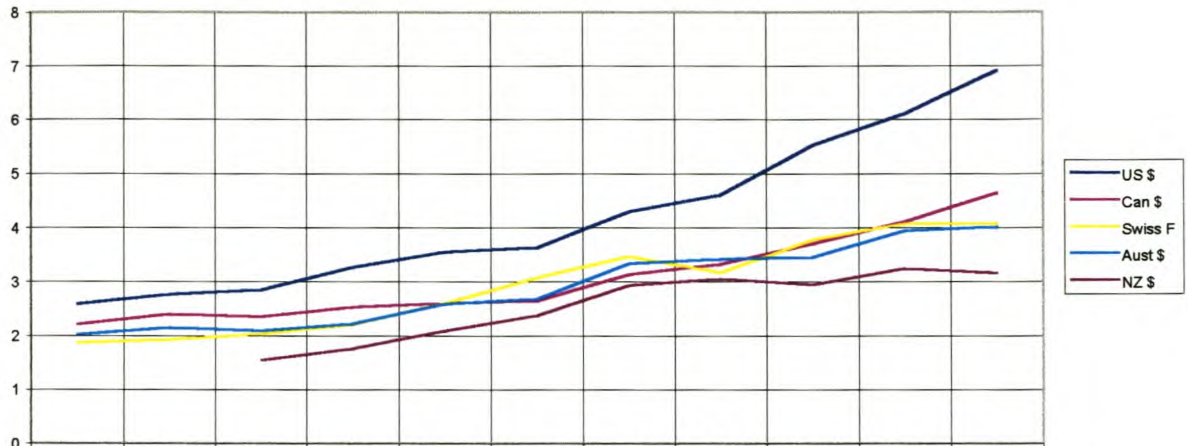
Figure 5.14: Diesel prices: South Africa vs. other countries

Considering the current political turmoil in the Middle East, it is difficult to predict with any reliability what the future international oil price will be. When considering the theories described by Porter (1990) and Buys (2000) regarding the impact of scarce resources in the development of technology, then one can assume that as the price of diesel increases, more creative solutions will be found for reducing energy consumption. There is thus a trade-off between the increasing cost of fuel on the one hand and innovative solutions to saving energy on the other. The net effect of high diesel prices will thus not necessarily have a major impact on harvesting costs. It could be foreseen that a technological breakthrough could be achieved in finding an alternative source of energy in the next decade. This could totally substitute the internal combustion engine (RSG, 2001). It is, however, not realistic to expect that such a breakthrough will translate through to harvesting machines by 2010. When the new technology is introduced, it would remain at the bottom end of the S-curve for some time, prior to major substitution in all vehicles and equipment.

b) Increase in machine cost

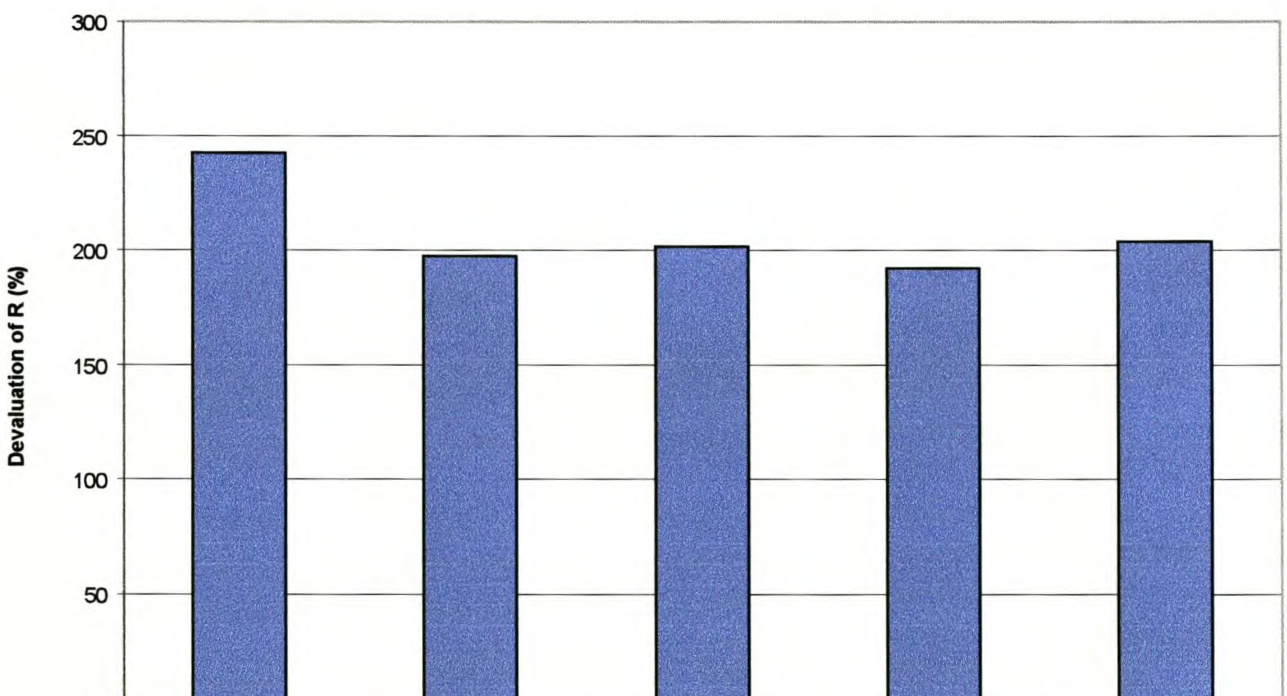
Considering the fact that the rationalisation of machine suppliers and the resultant increase in the globalisation of the forestry machine market, exchange rates will become increasingly important to countries that are importers of technology. Although South Africa has limited forest machine production capacity, through Bell Equipment, it is essentially a consumer of technology. The South African Rand has shown significant levels of fluctuation against certain currencies over the last decade (Figure 5.15), most profoundly against the US Dollar (Figure 5.16). However, it has remained stable against other countries, notably the New Zealand Dollar, over the last 6 years. The major producers of forest machines are the USA, Canada, Sweden and Finland. However, the Waratah harvester head range is currently being manufactured in New Zealand. Fitting these heads to Asian built excavators (e.g. Kato, Hitachi and Komatsu) could have a significant bearing on capital outlay when CTLM systems are being considered as a possible alternative harvesting system.

However, the bulk of the full range of equipment constituting the Forest Engineering value chain will continue to be imported from the USA, Canada, Sweden and Finland over the next decade. If the Rand continues with its current downward trend against certain currencies or even devaluates at a more rapid rate in future, then this will have a significant effect on the type of harvesting systems best suited to the South African forestry environment. Exchange rate predictions are not an exact science. It has many factors impacting on it, both locally and internationally. Considering past trends one can possibly assume that the Rand will not improve against the relevant currencies and that it could devaluate more rapidly in the future, depending on Government policies, local economic growth and international events. A most optimistic view would be that the Rand would maintain its current value.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
US $	2.5882	2.7612	2.8519	3.2669	3.549	3.6264	4.2941	4.6074	5.5258	6.1131	6.9212
Can $	2.20701832	2.40269101	2.35238767	2.53100481	2.600104	2.64270613	3.12793244	3.32557366	3.70507595	4.11353353	4.64468184
Swiss F	1.86185068	1.92715359	2.02757502	2.20799293	2.5947068	3.0684259	3.46140533	3.17258883	3.77643505	4.07166124	4.08830744
Aust $	2.01938611	2.14592275	2.09424084	2.21680337	2.59201659	2.68817204	3.33111259	3.41997264	3.45184674	3.94321767	4.0192926
NZ $			1.54774803	1.76056338	2.09424084	2.38038562	2.92825769	3.04692261	2.94464075	3.23939099	3.15258512

Figure 5.15: Exchange rates of selected countries (Standard Bank, 2001)



	US $	Can $	Swiss F	Aust $	NZ $
Percent	242.6873313	197.445425	201.635323	191.9212219	203.6885246

Figure 5.16: % devaluation of SA Rand between 1992 and 2000 (Standard Bank, 2001)

When analysing the cost of labour *vs.* machine costs over the period 1987 to 1997, it is evident that labour costs have increased significantly more (958%) over the period than machine costs (125% – 253%) (Meyer, 1999; Shackleton, 1999; van Eden, 1999). This is illustrated in Figure 5.17, where the cost increase of skidders and 3-wheeled loaders are compared with labour cost increases over a 10-year period, using 1987 as the base year. The reason for the high increase in labour cost is due to the unionisation of the forest industry since the late 1980's. The base from which wages were originally negotiated, however, was thus very low, resulting in the exponential increase over the relevant period.

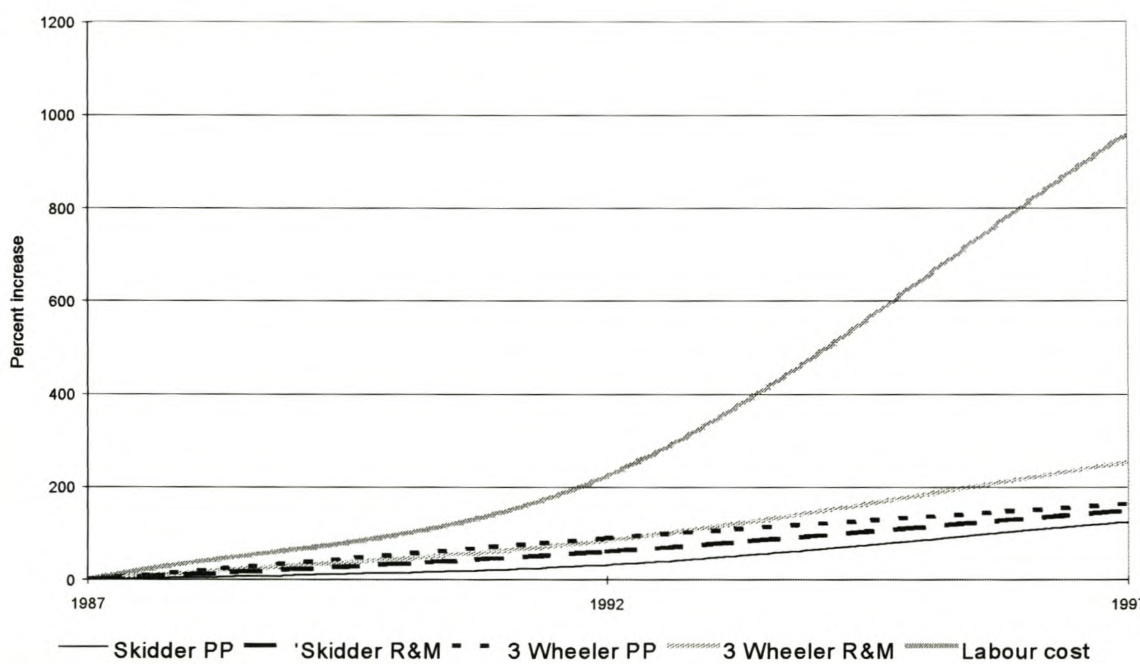


Figure 5.17: Increase in machine cost vs. labour cost (1987 to 1997)

5.5.2.3 Social-Cultural Forces

a) Population growth

The world's population is growing exponentially. This is also true for South Africa, as shown in Figure 5.18.

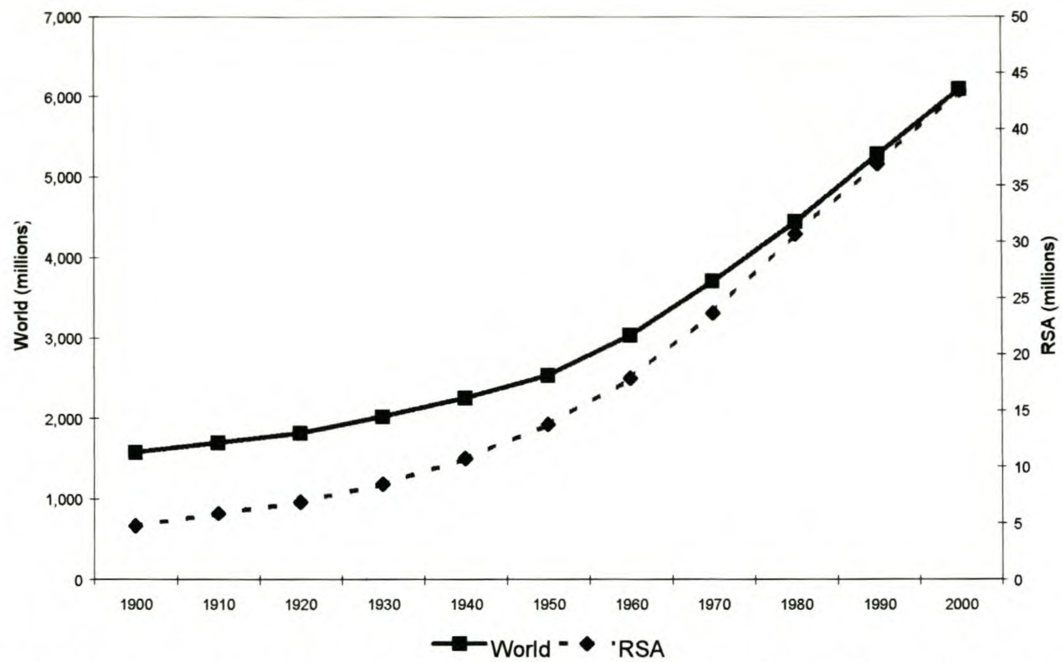


Figure 5.18: Population growth in the 20th century: World vs. South Africa (Oosthuizen, 1999)

The implication thereof is higher unemployment, both from a rural and urban perspective, especially when considering the age distribution of the population. The workforce is, however, becoming better informed and this will require greater levels of sophistication from the industry in dealing with labour issues. A paradox therefore arises, where, even though the country has a high unemployment rate, it cannot recruit skilled workers to work in the Industry. It is as true for the remainder of the South African economy, as it is for forestry. It is, for example, becoming increasingly difficult to recruit chainsaw operators in some geographic regions of the country, notwithstanding the fact that unemployment is rife in the specific area (Venter, 1997). Crime and violence are also a great threat to a stable economy in South Africa.

b) Worker profile in South Africa

The cost of labour has been a major change driver globally in the last decade and is expected to remain so in the next decade (Figures 5.1 and 5.2). When considering the increasing levels of sophistication of harvesting machines through technology improvements, then more skilled operators will be required to run these machines, leading to further increases in wage levels.

South African wage levels for timber harvesting have increased 958% between 1987 and 1997 (Figure 5.17). The average rates have also increased 178% over the period 1993-1999 (Figure 5.19).

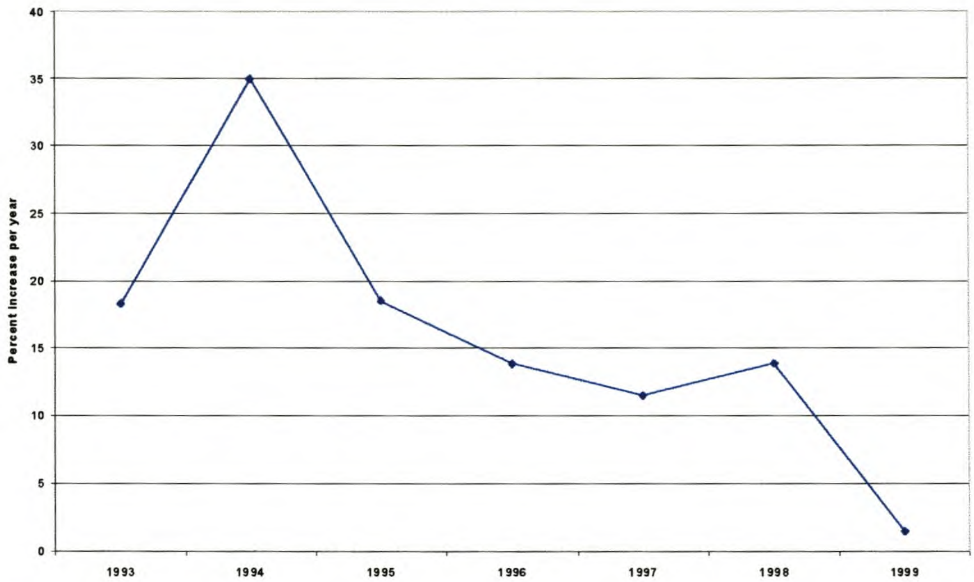


Figure 5.19: Increase in labour cost in harvesting in South Africa (Meyer, 2001)

Figure 5.19 also shows that wage level increases have become progressively smaller since 1994. The major reason for this could be due to the huge trend towards outsourcing of operations over the last decade (Sappi is virtually 100% outsourced, Mondi is 80% outsourced). Contractors are currently paying their labourers significantly less that what has been paid traditionally by forestry companies. With the current trend of outsourcing all forestry operations, the Trade Unions will focus on contractors in the future. Forestry wages and wages of harvesting workers in particular, still lag significantly behind those in the USA, Canada, New Zealand, Australia, Sweden, Finland and Germany (personal observation). This is confirmed in Table 5.8, where a comparison is given between the wage rates in the Pacific Northwest (PNW) of the USA and South Africa (Kellogg, 2001).

Table 5.8: A comparison of wage rates in South Africa and the Pacific Northwest of the USA (Exchange rate: $1=R8.20)

Operator type	Wage in South Africa	Wage in Pacific Northwest
Chainsaw operator	R13.30	R254.20
CTL machine operator	R19.70	R262.40
Grapple skidder operator	R16.60	R231.20
Average	R16.53	R249.26

The wages in the PNW is a fair reflection of the situation in developed countries and it shows on average a 1407% wage differentiation with South Africa. When considering this significant wage gap and combined this with current Trade Union strategies in forestry and the minimum wage of R1 500 per month being paid by the Department of Water Affairs and Forestry, one must assume that wages will continue to increase significantly over the next decade at significant levels. The result could be significant increases in the wage levels paid in all forestry operations. The low wages to workers employed in harvesting operations is supported by Manyuchi (2000), who found that most forestry workers fall in the R 20 – R 30 per day wage group in KwaZulu Natal (Figure 5.20).

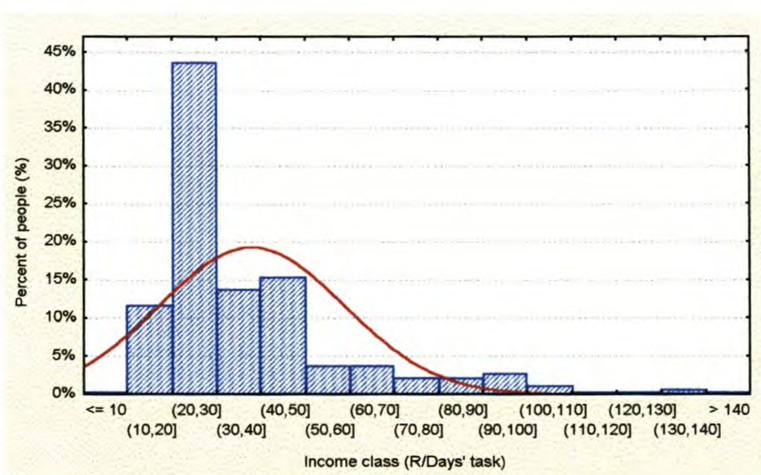


Figure 5.20: Wages of harvesting workers in KwaZulu Natal (Manyuchi, 2000)

Workers in harvesting operations in KwaZulu Natal are on average 34 years of age, as shown by Manyuchi (2000) in Figure 5.21. Although this exhibits a fairly well balanced age class distribution, the majority of the workers lie in the HIV/AIDS danger zone.

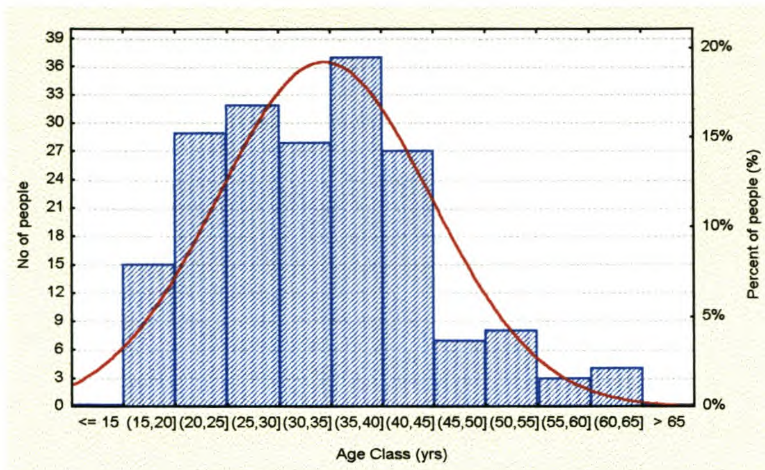


Figure 5.21: Age of harvesting workers in KwaZulu Natal (Manyuchi, 2000)

About 25% of harvesting workers in KwaZulu Natal do not have formal academic qualifications, with the average school qualification being standard 4. Figure 5.22 reflects these qualification levels.

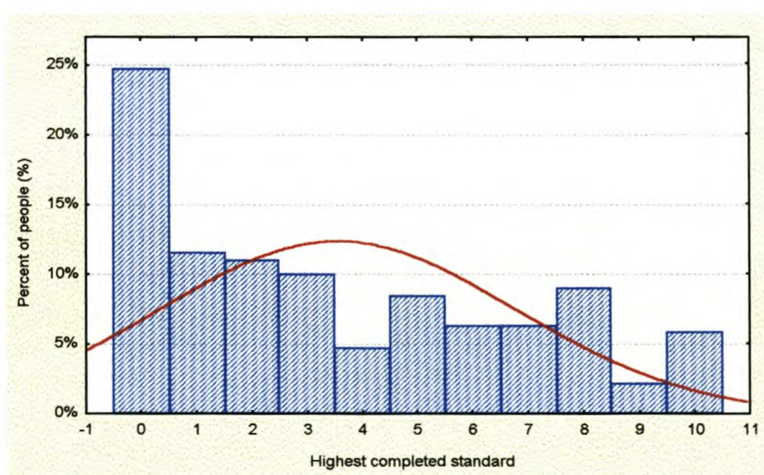


Figure 5.22: Formal qualification levels of forestry workers in KwaZulu Natal (Manyuchi, 2000)

Figure 5.23 shows that in KwaZulu Natal all machine operators, truck drivers and stackers are male. Females dominate in debarking and the marking of logs for crosscutting.

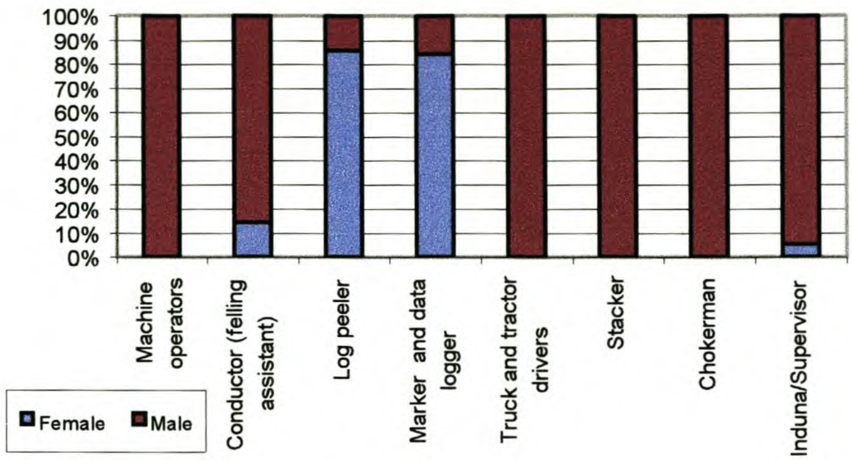


Figure 5.23: Male vs. female harvesting workers in KwaZulu Natal (Manyuchi, 2000)

Manyuchi (2000) found that workers are employed for longer periods by private companies than what they are by contractors in KwaZulu Natal.

There has been a significant increase in the emigration of skilled foresters from South Africa in recent years (personal observation). Between 1995 and 2000, eight qualified forest engineers left the country, out of a total pool of about 40 (Grobbelaar, 2000). It constitutes 20% of the total number and this situation should be addressed by the Industry as a matter of urgency, if it wants to prosper in the future.

c) Increase in health and safety awareness

The total cost of labour is not only a function of wage levels and other direct costs (e.g. UIF, pension), but also the influence of other hidden costs, most profoundly health and safety related costs and their effect on productivity. Figure 5.24 shows that the direct costs involved in accidents is only the tip of the iceberg. In this American-based study, it was found that uninsured and miscellaneous costs could be as much as 53 times the amount of the insured costs.

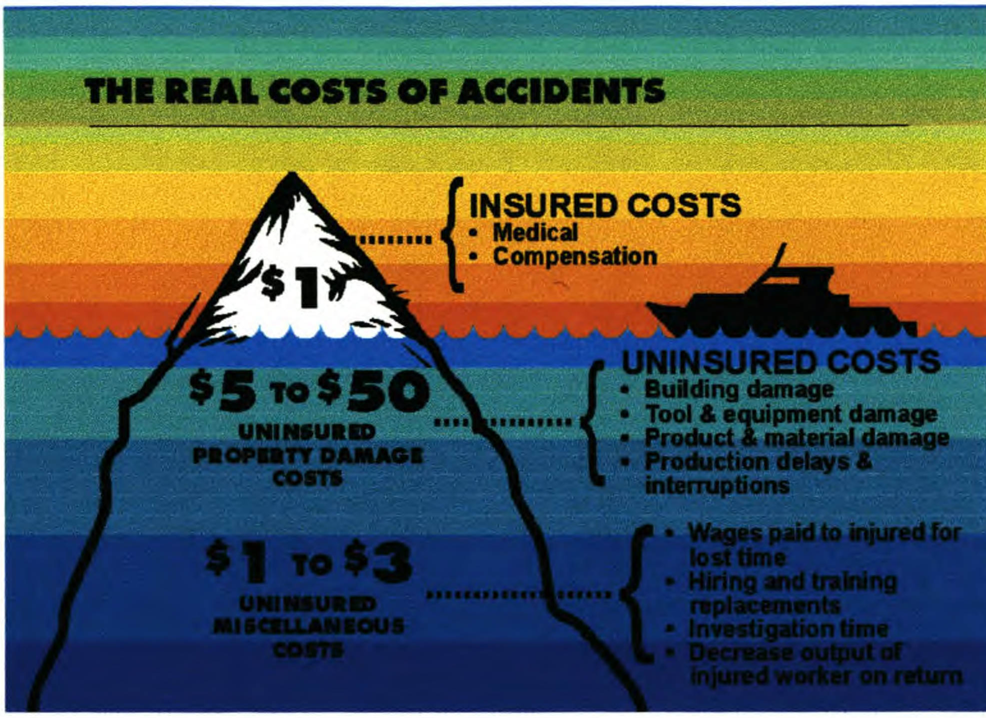


Figure 5.24: The hidden costs of an accident (Conradie, 2001)

It is essential that the industry operates within internationally accepted safety standards in order to be competitive. Health and safety have not been identified as significant global change drivers (Figure 5.1) and will only become slightly more important over the next decade (Figure 5.2). The reason is probably because of the high levels of safety already achieved in the countries represented in the Delphi study. This has been achieved primarily through the payment of high workman's compensation and UIF in these countries, particularly for dangerous activities such as motor manual tree felling. The expected future relevance of the cost of labour as a change driver could be attributed to further increases in workman's compensation in the relevant countries. South Africa has experienced a 95% increase in workman's compensation from 1991 to 1995 (de Wet, 2001). This is in line with international trends and the upward trend can be expected to continue in the future. It is also true that accidents are expensive in terms of loss in productivity. High labour turnover should be avoided if a company intends to achieve sustainable productivity improvement. It is true for both labour intensive and mechanised operations. If workman's compensation increases and if unions put pressure on contractors to increase wage rates, the inclination towards mechanisation will undoubtedly increase. Although AIDS is, strictly speaking, a health and safety issue, its potential impact is so great that it is addressed in a separate paragraph.

d) The impact of AIDS on the workforce

The first discovery of the disease was in 1980 when doctors began to observe clusters of diseases that previously had been extremely rare. Initially, most cases were seen in homosexual men. This then expanded to haemophiliacs, recipients of blood transfusions and intravenous drug users. The disease became known as the Acquired Immunodeficiency Syndrome, commonly known as AIDS (Whiteside and Sunter, 2000; AIDS; utexus.edu, 2001).

The virus that causes AIDS was then identified in 1983 by a French scientist, Lue Montagnier. It was named the Human Immunodeficiency Virus or HIV. People are said to be HIV positive when the HIV antibodies are detected in their blood.

HIV is relatively hard to transmit, with sufficient quantities required to enter the body in order to cause infection. It must pass through an entry point in the skin and/or mucus membranes into the blood stream.

The main modes of transmission, in order of importance are:

- unsafe sex;
- transmission from infected mother to child;
- the use of infected blood or blood products; and
- other modes of transmission involving blood, e.g. bodily contact involving open bleeding wounds (Whiteside and Sunter, 2000; CNN.com, 2001).

As with technology development, epidemics follow an S-curve, as reflected in Figure 5.25.

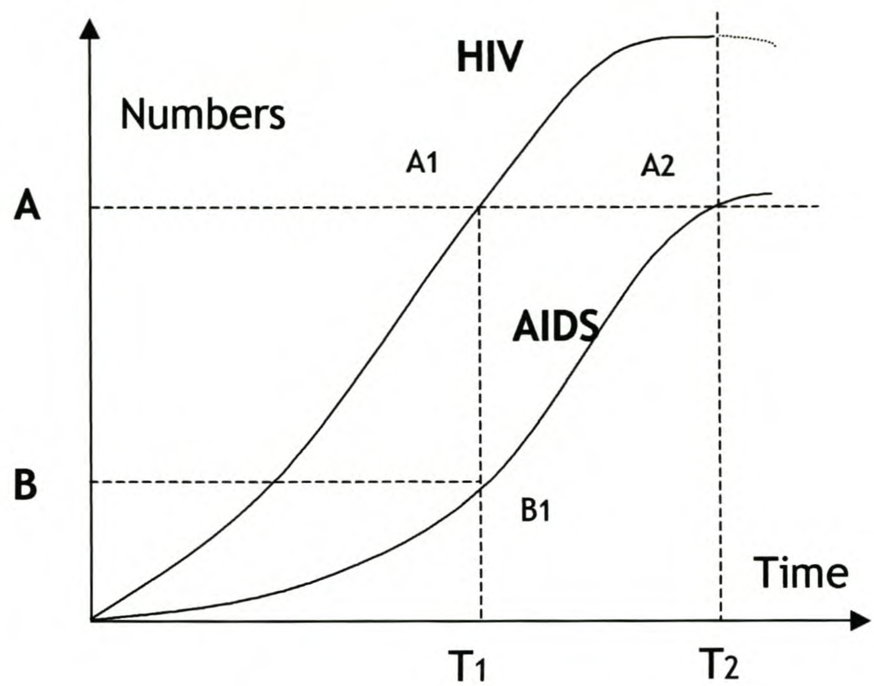


Figure 5.25: S-curve of HIV and AIDS development (Whiteside and Sunter, 2000)

What sets HIV and AIDS apart from other epidemics is that there are two curves. The HIV curve precedes the AIDS curve by six to eight years, reflecting the incubation period between first being infected and the onset of illness. HIV is therefore a leading indicator of future AIDS infection rates.

A summary of the status of the AIDS epidemic, as reported in December 1999, is given in Table 5.9.

In the view of some sources, Whiteside and Sunter (2000), are conservative in their estimates. CNN.com (2001) puts the number of incidents at 4 million and the prevalence at 24,5 million in 1999, for sub-Sahara Africa. Table 5.9 shows that 23,3 million people in sub-Sahara Africa have HIV or AIDS, constituting 70% of the world's infections in only 10% of the global population. AIDS related deaths would soon surpass the 20 million Europeans killed by the Bubonic plague epidemic of 1347 to 1351.

Table 5.9: Global status of HIV/AIDS (Whiteside and Sunter, 2000)

Region	**Epidemic started**	**Adults & children living with HIV/AIDS (Prevalence)**	**Adults & children newly infected with HIV in 1999 (incidence)**	**Adult prevalence rate (%)**	**Proportion of HIV-positive adults who are women**	**Main modes of transmission for adults living with HIV/AIDS**
Sub-Saharan Africa	Late '70s- early '80s	23,3 million	3,8 million	8,0	55	Hetero
North Africa & Middle East	Late '80s	220 000	19 000	0,13	20	IDU, Hetero
South & South-East Asia	Late '80s	6 million	1,3 million	0,69	30	Hetero
East Asia & Pacific	Late '80s	530 000	120 000	0,07	15	IDU, Hetero, MSM
Latin America	Late '70s- early '80s	1,3 million	150 000	0,57	20	MSM, IDU, Hetero
Caribbean	Late '70s- early '80s	360 000	57 000	1,96	35	Hetero, MSM
Eastern Europe & Central Asia	Early '80s	360 000	95 000	0,14	20	IDU, MSM
Western Europe	Late '70s- early '80s	520 000	30 000	0,25	20	MSM, IDU
North America	Late '70s- early '80s	920 000	44 000	0,56	20	MSM, IDU, Hetero
Australia & New Zealand	Late '70s- early '80s	12 000	500	0,1	10	MSM, IDU
Total		33,6 million	5,6 million	1,1	46	

Some facts demonstrating the extent of the disease are:

- Twelve million people have died of AIDS in sub-Saharan Africa over the last 10 years.
- Each day 5 500 people die of AIDS in sub-Saharan Africa.
- In 1998, AIDS was the largest killer, accounting for 1,8 million deaths from malaria and nine times the deaths from T.B.
- A 15 year old in Zambia has a 60% chance of dying from AIDS.
- Africa can expect to have up to 10 million AIDS orphans in future. (Creamer, 2000; Whiteside and Sunter, 2000).

In the Southern African region most countries are grossly infected. Table 5.10 shows the estimated infection rates for Southern Africa.

Table 5.10: The status of HIV/AIDS in Southern Africa (Whiteside and Sunter, 2000)

Country	Adult prevalence rate (%)	Number of adults & children living with HIV/AIDS	Estimated number of orphans
Botswana	25,1	190 000	25 000
Lesotho	8,4	85 000	8 500
Mozambique	14,2	1 200 000	150 000
Namibia	19,9	150 000	7 300
South Africa	12,9	2 900 000	180 000
Swaziland	18,5	84 000	7 200
Zambia	19,1	770 000	360 000
Zimbabwe	25,8	1 500 000	360 000
Total/average	Av. 12	10 805 000	2 214 000
Note: Orphans are defined as children under the age of 15 who have lost their mother or their mother and father.			

Because of the growth of the HIV prevalence and the failure to control the spread of HIV, South Africa faces a major AIDS epidemic. Instead of being able to focus on prevention activities the country is consequently about to have to deal with the consequences of large-scale conversion from HIV to AIDS. In terms of the impact, a great deal is unknown, as the epidemic has not yet run its course anywhere in the world (Whiteside and Sunter, 2000). Fourie (2001) has also shown that Southern Africa is the worst of all regions of the world hit by HIV infections.

Table 5.11 gives a projection of HIV/AIDS in South Africa to the year 2010.

Table 5.11: Projection of HIV/AIDS for South Africa (Whiteside and Sunter, 2000)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Adult HIV prevalence rate (%)	8,9	10,7	12,4	14,0	15,3	16,5	17,6	18,6	19,5	20,2	20,7	21,1	21,4	21,7
HIV prevalence (000's)														
- adults	2 128	2 598	3 053	3 475	3 871	4 235	4 577	4 887	5 161	5 387	5 555	5 675	5 764	5 830
- children	87	114	144	173	201	226	250	271	291	309	326	342	354	365
- total	2 215	2 712	3 197	3 648	4 072	4 461	4 827	5 158	5 452	5 696	5 881	6 017	6 118	6 195
AIDS cases (000's)														
- adults	57	83	118	161	213	272	336	403	469	532	588	635	674	705
- children	18	25	33	42	50	59	67	74	81	88	93	99	104	108
- total	75	108	151	203	263	331	403	477	550	620	681	734	778	813
AIDS deaths (000's)														
- adults	47	67	93	125	161	203	246	291	334	373	408	437	460	478
- children	14	19	25	31	36	42	47	52	56	60	64	68	71	73
- total	61	86	118	156	197	245	293	343	390	433	472	505	531	551
Orphans (000's)	60	96	147	217	309	425	568	734	921	1 123	1 333	1 543	1 746	1 936

Note: Adult denotes a person 15 to 59 years old, children are 0-14 years old; and orphans are children up to 14 years old who lost their mother due to AIDS

The impact of HIV on mortality is illustrated in Figure 5.26.

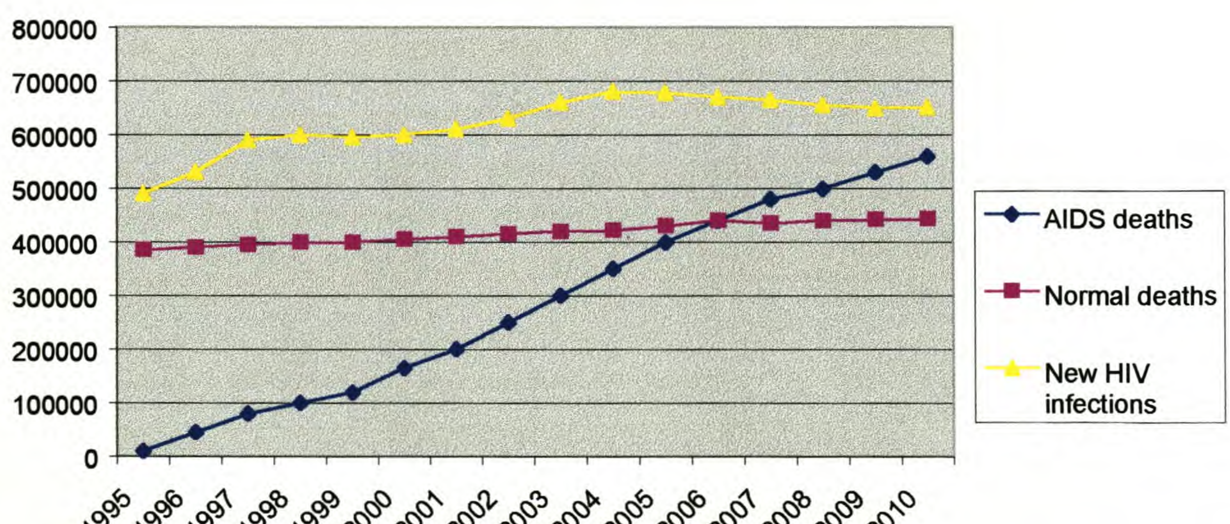


Figure 5.26: South African AIDS mortality rates up to 2010 (Whiteside and Sunter, 2000)

It shows the steady and inevitable rise in the number of deaths from AIDS. By 2006 there will be as many deaths from AIDS as from all other causes (Figure 5.26). AIDS mainly kills young adults in the economically active group. Steenkamp (2001) states that in August 2000, 15% of the forestry workforce in South Africa was already infected with HIV and that as many as 30% could be infected by 2010.

Whiteside and Sunter (2000) forecast the percentage of the workforce infected by 2010 to be 21%. Life expectancy is conversely projected to drop, as depicted in Table 5.12:

Table 5.12: Projected life expectancy in South Africa in 2010

	Male (years)	Female (years)
1999	50	54
2010	38	37

As South Africa enters the new century, it is clear that the epidemic is not yet having a measurable impact. Because the impact of AIDS is gradual, subtle and incremental, it may well be that the true impact on Government and the private sector will only be known when looking back from 2010 at what actually happened (and what should have been done). Even then, it will be necessary to isolate its effect from all the other factors that influence the economy, e.g. Government economic policy, export markets and interest rates.

Recently, South Africa was predicted to be at the threshold of renewed economic growth. In 2000 the economy was expected to grow by 3,5%, and the growth rate was to remain over three percent for the near future. Creamer (2000) believes that GDP will decline by as much as 2% due to AIDS.

Whiteside and Sunter (2000) noted that the AIDS epidemic was expected to have an adverse impact on the South African economy, and suggest that annual GDP growth would be between 0,3 and 0,4 percentage points lower than the no-AIDS baseline over the next 15 years. They list the implications thereof as follows:

- South Africa is already battling with a skills shortage. AIDS will exacerbate this and raise remuneration and replacement costs for companies.
- There will be a smaller labour force, with lower productivity and income, at the same time as an increased demand for services such as health and welfare. Lower tax revenues, combined with higher health spending, will put pressure on the Government's budget deficit. However, demand for housing as well as durable and non-durable goods could be negatively affected.
- A rise in the inflation rate, together with a smaller savings pool, could well put pressure on interest rates.
- Domestic savings may be squeezed to a point where foreign investment is vital to plug the gap. However, AIDS and the perception that it creates, may deter such investment.
- By 2006 the total loss of productivity could be about 20% in the mining industry alone (Creamer, 2000).
- A prevalence rate above five percent not only makes the disease more expensive and difficult to contain; it also starts seriously reducing economic growth. South Africa is at double that threshold right now.

The effects of HIV/AIDS on future population growth and labour force participation are difficult to predict, as is the economic and social impact. However, it suggests that population growth may slow to close to zero percent by 2010, with the annual growth of the working age population declining from over two percent in 2000 to under 0,5 percent by 2008.

Household structure and behaviour will change as the size, composition and productivity of the labour force are affected. HIV/AIDS is more prevalent among the economically active part of the population, thus affecting economic activity through a loss of skills and experience. Labour productivity will decrease, owing to absenteeism and illness of workers, and unit labour costs will increase as firms pay more for medical aid and group life or disability coverage. Initial evidence suggests that AIDS mainly affects lower income or skills groups (e.g. migrant or mobile labourers) but the future pattern is still unclear. Whiteside and Sunter (2000) suggest an HIV prevalence in 2003 of 12 percent among highly skilled workers, 20 per cent among skilled workers and 27,2 percent among unskilled workers.

Declining life expectancy and job losses in families will also affect the dependency ratio - the ratio of the non-working age population to the working population. More orphaned children and child-headed households, combined with fewer economically active people, will burden family support systems, with implications for the future development of South Africa's social security systems. Floyd (2001) states that 30% of babies born to HIV positive mothers are affected.

Table 5.13 outlines the effect of HIV/AIDS on the economy. The conclusion from the Table is that HIV/AIDS will be with us in South Africa and its effect will notably be devastating. The future success in preventing the spread of the disease and the treatment of AIDS patients is a key uncertainty, but to some extent a key controllable.

Table 5.13 Progression of HIV / AIDS cases and costs of workforce (Whiteside and Sunter, 2000)

Progression of HIV/AIDS in the workforce	Economic impact of individual case	Economic impact of all cases
1 Employee becomes infected with HIV/AIDS	▪ No costs to company at this stage	▪ No costs to company at this stage
2 HIV/AIDS –related morbidity begins	▪ Sick leave and other absenteeism increases ▪ Work performance declines due to employee illness ▪ Overtime and contractors' wages increase to compensate for absenteeism ▪ Use of company's on-site health clinics increases ▪ Payouts from medical aid schemes increase ▪ Employee requires attention of human resource and employee assistance personnel	▪ Overall productivity of workforce declines ▪ Overall labour costs increase ▪ Additional use of medical aid benefit causes premiums to increase ▪ Additional medical staff must be hired at the company's health clinics ▪ Managers begin to spend time and resources on HIV related issues ▪ HIV/AIDS interventions are designed and implemented
3 Employee leaves workforce due to death, medical boarding, or voluntary resignation	▪ Payout from death benefit or life insurance scheme is claimed ▪ Pension benefits are claimed by employee or dependants ▪ Other employees are absent to attend funeral ▪ Funeral expenses are incurred ▪ Company loans to employee are not repaid ▪ Co-workers are demoralised by loss of colleague	▪ Payouts from pension cause employer and/or employee contributions to increase ▪ Returns on investment in training are reduced ▪ Morale, discipline and concentration of other employees are disrupted by frequent deaths of colleagues
4 Company recruits a replacement employee	▪ Company incurs costs of recruitment ▪ Position is vacant until new employee is hired ▪ Cost of overtime wages increases to compensate for vacant positions	▪ Additional recruiting staff and resources must be brought in ▪ Wages for skilled (and possibly unskilled) employees increase as labour markets respond to the loss of workers
5 Company trains the new employee	▪ Company incurs costs of pre-employment training (tuition) ▪ Company incurs cost of in-service training to bring employee up to level of old one ▪ Salary is paid to employee during training	▪ Additional training staff and resources must be brought in
6 New employee joins the workforce	▪ Performance is low while new employee comes up to speed ▪ Other employees spend time providing on-the-job training	▪ There is an overall reduction in the experience, skill, institutional memory and performance of the workforce ▪ Work unit productivity is disrupted as labour turnover rates increase

e) Education and training

Globally, traditional forestry education has been under pressure to adapt in response to new emphases in forest management and to changes in the job market. Educational institutions are expected to produce forestry graduates with a wider array of knowledge and skills than before. The complex and dynamic nature of sustainable forest management (SFM) requires forest managers who have an expanded set of skills, are adaptable and are responsive to changing situations. The private sector and NGOs, which are increasingly important employers in the forestry sector, are looking for graduates with specific skills that were less needed in the past. Curriculum reform, expanded continuing education opportunities and a re-conceptualisation of the learning environment, are some of the responses to the new demands. Some of the required changes, as related to forest Engineering is discussed in paragraph 5.4.1.9.

Curriculum reform is probably the most obvious change in forestry education. A 1996 survey showed that more than 200 of the 750 forestry education and training institutions surveyed revised their curricula during the period 1989 to 1995 (FAO, 1996). Revised forestry curricula tend to place increased emphasis on such subjects as ecology, environmental sciences, natural resource management, community forestry, agro-forestry, marketing, management and administration. Some of the curriculum reform incorporates new techniques, learning models and styles, such as interdisciplinary problem-solving approaches, in addition to new content. In Malaysia, curricula were revised as part of a re-designing effort for forestry education, which included the development of a strategic plan and the restructuring of faculties and departments. In the Czech Republic, as in other countries in transition, forestry curricula are being modified in response to dramatic shifts in forest ownership patterns and other changes brought about by economic and political restructuring. The Czech Republic's education system, which was formerly nationally uniform, has been diversified and adjusted to individual regions to be more applicable to their respective circumstances.

Meaningful curriculum revision does, however, remain difficult. Traditional but still important subjects, such as harvesting and transport systems, still need to be taught while new subjects are continuously added, leading to difficult trade-offs. In a survey of its graduates conducted by the Tropical Agriculture Research and Higher Education Center (CATIE) 96 % thought that the profession's future lay in the private sector, while 91 % stated that little training was received in management and administration - skills in demand by the private sector (FAO, 1999).

Opportunities for learning outside the classroom are also increasing. Distance learning provides academic structure, but flexibility in the place and time of learning. New information and communication technologies, such as the Internet, provide immediate access to unprecedented quantities of information and educational resources. They are contributing to a reassessment of time and space in education, through concepts such as institutions without walls and learning as a lifelong endeavour. These technologies, and their rapid pace of evolution, as well as other changes, are contributing to an inversion of the traditional learning pyramid, older professionals having to look to younger ones for information, training and advice. The offering of the Saasveld B Tech and Diploma courses via distance learning, is an example of the successful application thereof in South Africa.

Significant changes are coming about because of both decreased public support for forestry education and training and the increased involvement of the private sector and NGO's in these activities. New strategic alliances between public and private institutions are emerging in some places. ForKom, a forestry forum in Indonesia involving private forest companies, Government agencies, the Forestry Training College and international donors, is an example of an informal co-ordination for human resource development in the forestry sector. In some places, private companies are co-sponsoring courses with universities in subjects of specific interest to them.

Traditional institutions will be forced to explore ways of being more flexible, such as allowing course work from a broader range of disciplines, and giving credit for work experience and training at different institutions. Continuing education and in-service training programmes will have to be more frequently used and their contents and presentation methods improved. Adult education and training approaches, that will help foresters continue to learn and to update their skills, will be increasingly important. Dynamic partnerships and alliances between a range of organisations -

private sector, public sector and non-Governmental - in the development of education and training programmes, will need to become more common. For this to materialise forestry sector bodies in South Africa will be required to actively lobby Government and give direction on how to gain the most value out of this new education method (FAO,1999).

5.5.2.4 Technological forces

As with the world population, and indeed probably due to it, the availability of information is increasing exponentially. More information leads to smarter technology. This in turn allows continuous productivity improvements in all aspects of our lives – both in terms of quality and quantity. As Sunter (1997) explains, technology is also making it possible for commodity prices to decrease over time. He refers to it as the "falling price boom". Every new skidder model has the capability of increasing productivity by at least 5% (White, 1995). This fact, combined with lowering of componentry costs through rationalisation programmes as machine manufacturers become increasingly globalised, should contribute to a reduction in machine costs. As discussed earlier, this will be further enhanced by a focus on more energy efficient machines in the future.

Technology improvements in hydraulics are contributing to a trend of hydrostatic machines replacing traditional power shift drive machines (Brink, 2000).

Improvements in tyre technology are allowing for reduced ground disturbance and potential soil compaction. This includes tyre size, dynamic tyre inflation through CTI and improvements in tyre construction.

As the stability of machines is improved, through the lowering of the centre of gravity (e.g. self levelling cabs), the use of more appropriate tyre/track configurations and improvements in the drive train (e.g. hydrostatic drives), machine manufacturers are moving towards larger machines, particularly for extraction. This was very prevalent at the recent Demo Canada Exhibition, held in Kelowna, British Columbia (Brink, 2000) The above technology improvements are also allowing ground-based equipment to safely negotiate steeper slopes than was possible in the past. A prototype machine specifically being developed to handle versatile slopes has made its appearance in Japan. The Forestry and Forest Products Research Institute at

Ibaraki, Japan, has built the Tri-Track Mover to operate as a prime carrier on that country's steep, fragile slopes. It consists of three pairs of tracked units, each equipped with a diesel engine and hydrostatic drive mechanisms. The three units are connected with height-adjustable arms which support the machine's working gear and which swivel, enabling the machine to remain level on 60 percent slopes, while crossing over obstacles, such as rocks, stumps or tree seedlings up to 1,3 metres tall (Drushka and Konttinen, 1997). Figure 5.27 shows the Tri-Track Mover in operation.

Figure 5.27: The Tri-Track Mover in operation (Drushka and Konttinen, 1997)

Because the reduction of environmental impacts is expected to be the most prominent global change driver over the next decade, a significant portion of R&D will be channelled towards the development and improvement of environmentally friendly harvesting machines. Some of the more recent developments in this regard are discussed in paragraph 5.5.2.5 under environmental forces.

5.5.2.5 Environmental forces

a) Machine technology

The importance of environmental impacts of timber harvesting operations have been highlighted in paragraph 5.4.1.6(a), with environmental impacts being identified as being the number one change driver in the next decade. South Africa will thus have to focus progressively more on environmentally sound harvesting techniques. Sound planning forms the core of achieving success. Even though the industry has focused on training foresters how to plan, it is not well implemented infield. A great deal of this expertise was lost when companies swung away from own operations to contractor operations.

Future harvesting machines will continue to improve their ability to minimise site impacts, such as the prototype "environmental harvester" developed in collaboration with Skogsforsk (Fryk, 1997). The harvester enables one machine to do the work of two (harvester and forwarder), leading to a partial or total elimination of the individual elements of the work, on condition that the timber is processed directly into the bunk of the harvester. Initially, the harvester was viewed as an option only for use in thinnings, with short extraction distances. However, the concept has expanded to include the harvesting of clearfelling stands. Some manufacturers are referring to it as a Combi machine and some prototype models are showing promise regarding clearfellings, so long as the lead distances are not too long and the assortments are limited (Thor, 2001). Two examples of these prototypes are shown in Figures 5.28 and 5.29.

Figure 5.28: The Valmet 801 Combi machine (Grafton, 2001)

Figure 5.29: The Pika Combi machine (Grafton, 2001)

The walking feller buncher, built by Plustech in Finland, is probably the most sophisticated harvesting machine ever built, even though the idea of a walking machine is not new. An earlier version was the three-legged Menzie Muck, which appeared in Switzerland in the 1970's. Because its movement was operator controlled, it was slow and cumbersome and disappeared off the market (Drushka and Konttinen, 1997). Figure 5.30 below shows a photograph of the Plustech walking machine.

Figure 5.30: The Plustech walking machine (Drushka and Konttinen, 1997)

The Plustech walking machine is a radically improved version of the old Menzie Muck, its six legs being computer- as opposed to operator controlled. The operator simply decides on the direction of travel and the computer controls the motion of the legs, which are equipped with sensors to detect unstable ground. The future might show that this walking machine could develop into a fleet footed runner, capable of bounding lightly through the forest while carrying a load of logs.

The evolutionary changes in forest machines over the past century provide some indications as to how these machines might develop over the next century. Looking at the history of logging, it is evident that entire lines of equipment may disappear, almost overnight, for reasons that have nothing to do with their inherent capabilities. For instance, the various machines that made up the steam-powered railway logging technology, which evolved in North America during the late nineteenth and early twentieth centuries, were displaced rapidly by new kinds of machines powered with internal combustion engines. Likewise, dozens of mechanical devices utilising cables – such as loaders and bulldozers, were replaced in the 1950's by hydraulic systems.

Events external to the Forestry Industry can dramatically influence its development. Major historical events such as the Great Depression and World War II suspended the development of logging machines for twenty years. After the war, a period of rapid evolution occurred in which numerous new machines appeared incorporating technical developments – hydraulics, alloys, electronics – invented during the war.

These changes cannot always be predicted where even small technological innovations can give an immense advantage to one type of machine over another. Someday, a new form of mechanical muscle, perhaps utilising a new generation of pneumatic equipment, might replace hydraulics and induce an evolutionary new technological S-curve of progress. It is, however, not foreseen that such a breakthrough will occur over the next 10 years.

b) Increased certification of forests

The impact of certification on global forestry and some of the trends in certification are discussed in Chapter 2. There is a strong correlation between the environmental impacts of harvesting and social pressure regarding non-forestry values on the one hand, and certification of forest products on the other. This is further enhanced by the fact that timber harvesting operations, together with forest roads, have the greatest impact on the environment and hence on the ability of a product to be certified.

Although there is currently no single internationally recognised certification body in the world, there are a number of organisations providing certification, which all have similar objectives in mind and all of which serve a specific niche market to whom forestry companies sell their fibre. In South Africa, two certification standards have been subscribed to in recent years, namely, the ISO 14001 environmental management system and FSC. South Africa had 32% of its plantation forestry area certified by February 1999, one of the highest figures of certification in the world (Marais, 1999). By July 2001, 830 000ha had been certified, representing 59% of the total plantation area. Godsmark (2001) forecasts that as much as 82% of the forestry area in South Africa will be certified by the end of 2003. Of this, 64% will have FSC certification and 18% will have achieved both ISO 14001 as well as FSC certification.

What is important is that forestry companies retain their certification once it has already been achieved, and to ensure that the particular certification system, be it ISO 14000 or FSC, remains recognised internationally, and that they serve the interests of the particular customers who are purchasing the raw material. However, over the last year, there have been concerns expressed by all the major companies who have been certified by FSC that the goal posts are continuously moved. This has cost the companies concerned a great deal, although has been necessary to retain their certification status. This needs to be carefully managed in the future. In conclusion, certification is currently a strength to the South African Industry, but has elements of being both an opportunity and a threat in future, depending on how it is managed by the industry.

5.6 A cross-impact analysis of the key change drivers

The cross-impact matrix is discussed in Paragraph 3.4.2.6. This tool is well suited to assist in identifying how change drivers that have been identified will impact one another and thereby establishing the key factors, which need to be considered in the scenario building exercise. Table 5.14 gives the cross-impact matrix for the relevant change drivers for South African timber harvesting operations. The selected change drivers are a combination of the drivers identified in the Delphi study (paragraph 5.4.1), those identified in the SWOT analysis for South Africa (paragraph 5.5.1) and the environmental scanning exercise (paragraph 5.5.2). Note that high cross-impacts have been highlighted in red.

Table 5.14: Cross-impact matrix of South African change drivers

	Political	Unions	Certification	Crime	Economic	Fuel price	Capital cost	Globalisation	Social	Labour cost	Public pressure	Health & safety	AIDS	Technological	Productivity	Fuel efficiency	Environmental	Harvest Impacts
Political	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
> Unions	*	*	L^+	0	*	0	0	H^-	*	H^+	L^-	H^+	H^-	*	H^-	0	*	L^-
> Certification	*	L^-	*	0	*	0	M^+	M^+	*	M^+	M^-	M^+	L^-	*	H^-	0	*	H^-
> Crime	*	0	M^-	*	*	0	M^-	H^-	*	M^-	L^-	L^-	L^+	*	H^-	0	*	0
Economic	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
> Fuel price	*	0	0	0	*	*	0	0	*	M^+	0	0	0	*	0	H^+	*	0
> Capital cost	*	L^-	H^-	0	*	0	*	0	*	L^+	L^+	L^-	0	*	H^-	H^+	*	H^+
> Globalisation	*	M^-	H^+	L^-	*	0	0	*	*	M^+	H^-	H^+	L^-	*	M^+	0	*	H^-
Social	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
> Labour cost	*	H^-	L^+	L^-	*	0	0	L^-	*	*	0	M^+	M^+	*	H^-	0	*	L^-
> Public pressure	*	H^+	L^+	L^-	*	0	0	M^-	*	M^+	*	M^+		*	0	0	*	H^-
> Health & safety	*	M^-	L^+	M^-	*	0	0	M^+	*	H^+	L^-	*	M^-	*	M^-	0	*	L^-
> AIDS	*	H^+	L^-	H^+	*	0	0	H^-	*	H^+	H^+	H^-	*	*	H^-	0	*	L^+
Technological	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
> Productivity	*	M^+	M^+	0	*	0	L^-	H^+	*	0	0	L^+	0	*	*	0	*	H^-
> Fuel efficiency	*	0	L^+	0	*	0	0	0	*	L^-	0	0	0	*	M^+	*	*	L^-
Environmental	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
< Harvest Impacts	*	0	H^+	0	*	0	H^+	H^+	*	L^+	M^-	L^+	0	*	H^-	L^+	*	*

The high cross-impacts, highlighted in red, are summarised in Table 5.15. As discussed in Chapter 4, scenarios are primarily built around key uncertainties. It is therefore necessary to identify these, as reflected in the last column of Table 5.15. Twelve key uncertainties have been identified in this Table.

Table 5.15: Summary of high cross-impacts and the rating thereof

A.	**POLITICAL ENVIRONMENT**	**RATING**
1.	An increase in unionisation / labour laws will decrease globalisation	1
2.	An increase in unionisation / labour laws will increase labour cost	2
3.	An increase in unionisation / labour laws will improve health & safety	2
4.	An increase in unionisation / labour laws will decrease the effect of AIDS	3
5.	An increase in unionisation / labour laws will decrease productivity	2
6.	An increase in certification will decrease productivity	2
7.	An increase in certification will decrease harvesting impacts	2
8.	An increase in the crime rate will decrease global competitiveness	3
9.	An increase in the crime rate will decrease productivity	3
B.	**ECONOMIC ENVIRONMENT**	**RATING**
10.	An increase in the fuel price will increase fuel efficiency	3
11.	An increase in the cost of capital will decrease certification	3
12.	An increase in the cost of capital will decrease productivity	3
13.	An increase in the cost of capital will increase fuel efficiency	3
14.	An increase in the cost of capital will increase harvesting impacts	2
15.	An increase in global competitiveness will increase certification	1
16.	An increase in global competitiveness will decrease public pressure	1
17.	An increase in global competitiveness will increase health & safety	1
18.	An increase in global competitiveness will decrease harvesting impacts	2
C.	**SOCIAL ENVIRONMENT**	**RATING**
19.	An increase in labour cost will decrease unionisation labour laws	2
20.	An increase in labour cost will decrease productivity	3
21.	An increase in public pressure will decrease unionisation	2
22.	An increase in public pressure will increase productivity	2
23.	An increase in health & safety will increase labour cost	2
24.	An increase in the effects of AIDS will increase unionisation	2
25.	An increase in the effects of AIDS will decrease global competitiveness	1
26.	An increase in the effects of AIDS will increase labour cost	3
27.	An increase in the effects of AIDS will increase public pressure	2
28.	An increase in the effects of AIDS will decrease health & safety	3
29.	An increase in the effects of AIDS will decrease productivity	3
30.	An increase in the effects of AIDS will increase the crime rate	3
D.	**TECHNOLOGICAL ENVIRONMENT**	**RATING**
31.	An increase in productivity will increase global competitiveness	1
32.	An increase in productivity will decrease environmental impacts	2
E.	**NATURAL ENVIRONMENT**	**RATING**
33.	A decrease in harvesting impacts will increase certification	2
34.	A decrease in harvesting impacts will increase the cost of capital	2
35.	A decrease in harvesting impacts will increase global competitiveness	1
36.	A decrease in harvesting impacts will decrease productivity	2

1 = Key certainties
2 = Key controllables
3 = Key uncertainties

5.7 The Scenarios for South Africa

5.7.1 Building a scenario matrix

The 12 key uncertainties are summarised below:

1. An increase in unionisation / labour laws will decrease the effect of AIDS.
2. An increase in the fuel price will increase fuel efficiency.
3. An increase in the cost of capital will decrease certification.
4. An increase in the cost of capital will decrease productivity.
5. An increase in the cost of capital will increase fuel efficiency.
6. An increase in labour cost will decrease productivity.
7. An increase in the effect of AIDS will increase labour cost.
8. An increase in the effect of AIDS will decrease health & safety.
9. An increase in the effect of AIDS will decrease productivity.
10. An increase in the effect of AIDS will increase the crime rate.
11. An increase in the crime rate will decrease global competitiveness.
12. An increase in the crime rate will decrease productivity.

The above key uncertainties can be grouped into two broad categories :

The cost of machinery = 2, 3, 4, 5, 8,9,10,11,12
The cost of labour = 1, 6, 7, 8, 9,10,11,12

The scenarios should therefore be built around these two broad categories. Figure 5.31 sketches the possibility of 4 different outcomes for the South African Forestry Industry, covering all uncertainties. Judging by the importance of these two criteria in the Forest Engineering value chain throughout the world, it could be that they could be applied generically for scenario building for any country or region. They are not necessarily unique to South Africa. However this needs further investigation.

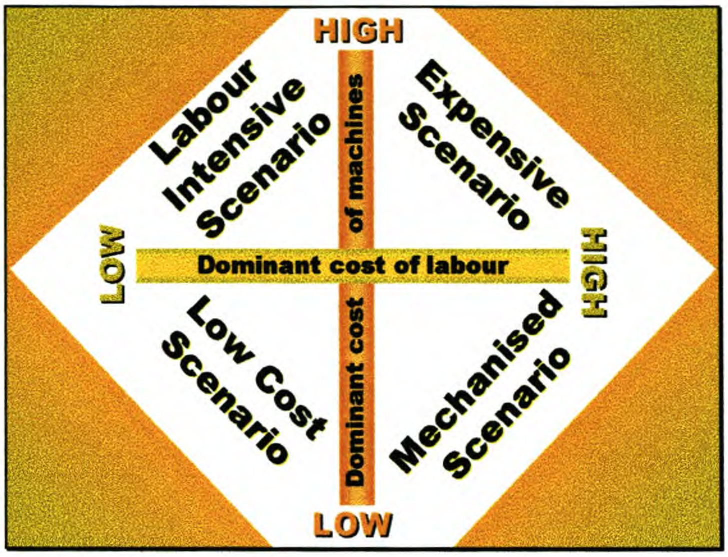


Figure 5.31: The scenarios identified for South Africa

5.7.2 Description of the four scenarios

5.7.2.1 Key certainties for all the scenarios

Under all scenarios, key certainties are as follows:

- In excess of 80% of all harvesting operations in South Africa will be outsourced.
- Technology improvements on machines will continue to improve their productivity. Machines will also be smarter with flexibility and machine "vision" being available. Machines will be able to negotiate steeper terrain conditions, with reduced impacts.
- Fuel costs will remain an important factor and energy will be forthcoming from internal combustion engines, powered by diesel. Significant improvements in fuel efficiency and energy-saving technologies on machines will, however, prevail.
- HIV/AIDS will be a major factor, without a cure for persons already infected. A vaccination could be developed to prevent the spread of HIV.
- Globalisation would have increased, with fewer brands of equipment being available. South Africa will be a consumer of harvesting machine technology.

5.7.2.2 Scenario 1: The mechanised scenario

Under this scenario, the socio-political arena will empower unions to become significantly more powerful than they currently are. This will lead to more stringent labour laws and the implementation of a high minimum wage in the Forestry Industry. The productivity of labour intensive operations will decrease due to the intensification of HIV/AIDS and the inability of employers to legally pay workers on incentive systems. Contractors will have embarked on HIV/AIDS programmes, both from a preventative and a treatment perspective. HIV/AIDS infected machine operators will be treated, in order to keep them healthy as long as possible. Screening for HIV/AIDS could possibly be applied to the recruitment of machine operators, possibly not legally.

Crime levels in South Africa will remain relatively high and will contribute to contractors moving away from labour intensive operations. The mechanised scenario doesn't imply more vehicles and equipment than the other scenarios, but rather different types of equipment. The labour intensive scenario, for example, will require a significantly larger fleet of transport vehicles, to transport workers to work. The less vehicles and equipment companies own, the less there is to protect. The South African National Qualifications Framework would have been fully implemented, primarily through Trade Union pressure, Government incentives, and a proactive forest industry.

South Africa will have become more of a global player and global players within the forest and forest products industry will dominate the Forestry Industry. The industry will consist of less corporate players than today.

Certification will have increased in importance, both globally and locally and the pressures that this will bring will lead to even further mechanisation, due to the high cost of maintaining social certification requirements if labour intensive systems are retained. Certification will also cause a general increase in harvesting costs. South Africa will have at least retained its current international ratings regarding investment potential, making machine repair and maintenance both easier and cheaper. Due to economies of scale, caused by the large number of machines in the market, the parts availability would have improved and be more affordable. For the same reason, mechanical skills will be more abundant and of an acceptable quality. The size of clearfelled areas would be well managed, leading to some increase in the cost of mechanised systems, which would be a relative advantage for CTLM systems over TL systems. Technology will have caused equal productivity gains in CTLM and TL systems, but CTLM processors will have made significant progress in "seeing" log defects and therefore better optimisation of sawlogs will be possible. "Global" brands of machines will prevail locally.

South Africa will have improved its current competitive position with regard to fuel prices, further promoting mechanisation. This will primarily be through the deregulation of the petroleum industry and a more favourable exchange rate. The increased cost implication of the depreciation of the Rand will not be as great as the increase in the cost of labour, for the reasons given earlier regarding labour cost increases. This implies that Government would have met its inflation targets set by the Reserve Bank and that interest rates would have been adjusted downwards, to the prime rate dropping below 10%.

5.7.2.3 Scenario 2: The low-cost scenario

This scenario will be the most beneficial to the South African Forestry Industry. In this scenario, labour costs will have been curbed, through the effective management of the HIV/AIDS epidemic. Although a cure is unlikely, a national programme would have been successfully implemented in preventing the spread of the disease, as well as dealing with infected persons. The cost of HIV/AIDS will have peaked and would be on the decline.

Trade Unions would have a more moderate approach with regard to wage levels and the use of incentives and would support companies promoting entrepreneurship. Contractors will range from small to very large, with owner-operators being common place. The education and training unit standards will be well implemented throughout the Forestry Industry.

The cost of labour would have been further reduced through the application of internationally accepted health and safety standards. Although labour costs would be low for general unskilled workers, the cost of skilled operators will be high.

Certification standards will be standardised globally and almost all forest products sold will be certified in one form or another, both locally and internationally. Public pressure would be great, but well managed by the industry. Certification will contribute to a better public perception of forestry.

The Government would have succeeded in curbing crime and violence within the country, which would negate this factor when harvesting systems are evaluated.

As in the first scenario, South Africa would improve its current competitive position with regard to fuel costs. Machines would, in any event, be more fuel efficient on a global scale, through technology improvements. Due to low inflation figures, low interest rates and a relatively favourable exchange rate, the purchase of new machinery will be more affordable. A sufficient number of machines will be available in the country to provide a critical mass for after-sales support. The cost of spare parts will therefore be at acceptable levels and the availability thereof will not be problematic.

Machines on offer would be "global" brands and the same technology improvements would prevail, as described in Scenario 1.

5.7.2.4 Scenario 3: The labour intensive scenario

Labour costs under this scenario will have been reduced by an effective HIV/AIDS prevention programme and by effectively dealing with the impacts caused by those infected by the disease. The Government would have contributed little to this success. It would have been primarily through international aid and industry sponsored programmes that this success had been achieved.

This scenario could include the option where, through regional instability in neighbouring countries, an increase in the influx of illegal immigrants occurs, many of whom work for very low wages for contractors. The Government would have lost control over this influx and a repatriation programme would be non-existent, due to cost or administrative problems.

South Africa would not have become a global player and the country's competitiveness rating would have dropped.

Trade Unions would be seen as "protecting the rights of a privileged few". However, most of the contractors' workers will not be unionised. International safety standards would not apply and certified plantations would be few.

Incentive systems will be introduced by Government to employ labour, but due to the conditions attached, contractors would rather employ illegal immigrants or South African workers at low wages.

With South Africa not enjoying a preferred investment status of emerging economies, inflation would be rife, exchange rates high and interest rates would climb. Fuel will be expensive, if available. The cost of machines will therefore be high, both to purchase and to maintain.

5.7.2.5 Scenario 4: The expensive scenario

Neither the Government, nor the private sector, would have paid attention to the HIV/AIDS epidemic and the country would be paying the ultimate price.

Unions would be more militant, pressurising companies to pay exorbitant wages whilst not addressing productivity. The illegal employment of non-union members would be strongly policed. There would be extreme implications with regard to non-compliance of health and safety issues.

As in the scenario 3, South Africa would not have become a global player. The low investment status, including high interest rates, of the country will lead to high machine costs, for the same reasons listed in scenario 3. The country would have lost the core of its skilled forester corps through emigration to forestry-based economies. The Government would have lost control over land claims and social pressure would lead to anarchy on forestry land, much of it owned by corporate entities.

The low road scenario will lead to a deterioration of all infrastructure, including the road network, which is the life blood of log transport. Rail will not be in a position to render a competitive alternative due to the inherent inefficiencies in the system. The industry will not be able to afford state-of-the-art forest equipment, not to mention its inability to keep them functioning due to a lack of trained personnel. Harvesting costs will be internationally uncompetitive when considering the cost of the full value chain up to mill delivery.

The low road option will result in a dissipated forest industry, where a lack of expertise will result in poorly managed forests. The final result will be poor growing stock and high harvesting and transport costs. Just-in-time delivery of high quality products will thus not be possible.

5.8 The financial evaluation of alternative systems under each scenario

5.8.1 Evaluation method

As discussed in Chapter 4, the use of the NPV method is the most efficient when a project runs over a few years. This method is used to evaluate the alternative systems against each other. A model was prepared, which includes all the relevant cash flows over the relevant period and discounts it back to the present time. Even though the cost model is primarily based on cash outflows, it is in essence a NPV calculation because the resale value of machines and marginal income streams for some systems are included as cash inflows. The marginal income streams allocated to some systems allow for the equitable comparison of all the systems included compared. For example, if a feller buncher causes less tree breakage during felling than a chainsaw, then the marginal income advantage of the feller buncher can be reflected as a cash inflow.

Because the model is primarily based on cash outflows, the system with the lowest negative value reflects the cheapest system. The various systems are therefore ranked from the lowest cost per cubic metre to the highest. Each system within each scenario has been based on the same annual volume of timber. All the calculations assumed a six year project lifespan. Where some machines have not reached obsolescence, the resale value of the particular machine was adjusted upwards accordingly. The NPV calculation was done on the pre-tax figures, as this is a costing exercise. However, the model does provide for after-tax calculations and IRR calculations. This has been included to expand the application of the model for a full project evaluation exercise, once the correct system has been selected for the particular forecast. The columns reflecting after-tax cash flows and IRR calculations are therefore not relevant to this particular exercise. No evidence exists that the ranking approach described above has been used before, to determine the optimal system for the Forest Engineering value chain.

5.8.2 Systems identified for each scenario

Based on the current systems in use in South Africa and expected future global developments (as outlined in Chapter 3) various possible harvesting systems have been developed for each of the four different scenarios.

Three distinct management objectives influence the choice of machines in the South African Forestry Industry, *namely:*

- Harvesting systems for pine sawtimber operations.
- Harvesting systems for pine pulpwood operations.
- Harvesting systems for *Eucalyptus* pulpwood operations.

The selected systems for each management objective vary from labour intensive to totally mechanised. DCF evaluations are given for 70 different combinations of machines (14 systems for the present and 14 systems for each of the 4 scenarios). These combinations are listed below:

a) *Pine sawtimber*

- System 1: Chainsaw / cable skidder / chainsaw / loader/ rigid truck
- System 2: Feller buncher / chainsaw / grapple skidder / chainsaw / loader/stinger steer truck/merchandising yard

- System 3: Feller buncher / clambunk skidder / processor / loader/rigid truck
- System 4: Harvester / forwarder/rigid truck

b) *Pine pulpwood*

- System 1: Chainsaw / manual load / tractor and trailer / tip /interlink truck
- System 2: Chainsaw / manual stack / forwarder/rigid truck and drawbar trailer
- System 3: Feller buncher / grapple skidder / static delimber and slasher / loader/ rigid truck and drawbar trailer
- System 4: Feller buncher/ grapple skidder/DDCL/ rigid truck and chip trailer
- System 5: Harvester / forwarder/ rigid truck and drawbar trailer

c) Eucalyptus *pulpwood*

- System 1: Chainsaw/manual debark/manual stack /hand load/tractor and trailer/tip/interlink
- System 2: Chainsaw/hand debark/hand stack/forwarder/rigid truck and drawbar trailer
- System 3: Harvester/clambunk/loader slasher/rigid truck and drawbar trailer
- System 4: Feller buncher/grapple skidder/DDCL/rigid truck and chip trailer
- System 5: Harvester/forwarder/ rigid truck and drawbar trailer

Annexures 10 (pine sawtimber), 11 (pine pulpwood) and 12 (*Eucalyptus* pulpwood) give the matrixes developed for each system. Each matrix illustrates the locality of each relevant activity for the harvesting systems described above.

5.8.3 Assumptions used in the cost evaluation

a) *General assumptions*

The environmental scanning exercise allows one to work within a narrower cone of certainty regarding the assumptions for the year 2010. The variables in the financial analysis that will change, are given in Table 5.16. This Table also gives the cone of certainty for each variable, as well as the allocated value used in each scenario. These are the values used in the financial analyses in Annexures 13, 14 and 15.

Table 5.16: The variable values used in the financial analyses

	Min value	Max value	Current	Mechanised	Labour intensive	Low cost	Expensive
Diesel price	150%	400%	100%	170%	250%	150%	400%
Petrol Price	150%	400%	100%	170%	250%	150%	400%
Oil as a % of fuel	5%	5%	5%	5%	5%	5%	5%
Supervisor	70%	600%	100%	500%	70%	600%	500%
Chainsaw operator	70%	500%	100%	500%	70%	200%	500%
Harvester operator	150%	1000%	100%	1000%	150%	700%	150%
Machine operator	80%	800%	100%	800%	150%	600%	800%
Truck driver 6 X 4	150%	700%	100%	600%	150%	500%	650%
Truck driver EC1	150%	700%	100%	600%	150%	500%	650%
Tallyman/scaler	70%	700%	100%	650%	70%	200%	700%
Chokerman	70%	700%	100%	650%	70%	200%	700%
Labourer	50%	600%	100%	600%	50%	270%	600%
Purchase price	70%	500%	100%	80%	400%	70%	500%
Useful life (mhrs)	75%	130%	100%	115%	80%	130%	75%
Resale value	5%	40%	20%	25%	7%	33%	5%
Fuel cons (l/mhr)	75%	130%	100%	82%	130%	75%	130%
R & M (R/mhr)	95%	500%	100%	110%	400%	95%	500%
License (R/yr)	70%	400%	100%	80%	200%	70%	400%
Insurance (R/yr)	7%	20%	5%	10%	20%	5%	20%
Tyre/track cost per tyre	95%	400%	100%	110%	300%	95%	400%
Tyre/track life (hrs/km)	75%	130%	100%	110%	75%	130%	130%
Pine 1m3 (m^3/shift)	60%	110%	100%	105%	70%	110%	60%
Pine 0.3m3 (m^3/shift)	60%	110%	100%	105%	70%	110%	60%
Eucalyptus (m^3/shift)	60%	110%	100%	105%	70%	110%	60%
Eucalyptus Harvester	60%	140%	100%	130%	70%	140%	60%
Manual stacking: pine pulp	60%	101%	100%	75%	90%	101%	60%
Manual loading: pine pulp	60%	101%	100%	75%	90%	101%	60%
Debark/stack: *Euc.* pulp	60%	101%	100%	75%	90%	101%	60%
Load: *Euc.* pulp	60%	101%	100%	75%	90%	101%	60%
Hurdle rate	4%	13%	5%	5%	11%	4%	13%

b) Machine cost calculation assumptions

Some general assumptions regarding machines are made. These are as follows:

- The price ratio between machines will remain constant.
- The resale value ratio between machines will remain constant.
- The insurance ratio between machines will remain constant.
- Lubricant consumption will remain at 5% of fuel consumption.

- Working days will remain constant at 221 per year.
- Productivity of machines for the present situation was obtained from SAFCOL (2000) and Shuttleworth (2000).

c) Pine sawtimber assumptions

The following assumptions are used for pine sawtimber:

- The average tree size: $1m^3$.
- The average slope: -10%.
- The average skidding distance: 200m.
- The average forwarding distance: 1000m.
- The average transport distance: 40 km.
- Feller buncher: 3% value recovery as opposed to chainsaw (Kewley and Kellogg, 2000).

d) Pine pulpwood assumptions

The following assumptions are used in the pine pulpwood calculations:

- The average tree size: $0,3m^3$.
- The average slope: -10%.
- The average skidding distance: 200m.
- The average forwarding distance: 1000m.
- The average short-haul distance: 10km.
- The average long-haul distance: 200km.
- R20/m^3 premium is paid for chips.

e) Eucalyptus *pulpwood assumptions*

The *Eucalyptus* pulpwood assumptions are given below:

- The average tree size: $0,22m^3$.
- The average slope: -10%.
- The average skidding distance: 200m.
- The average forwarding distance: 1000m.
- The average short-haul distance: 10km.

- The average long-haul distance: 200km.
- R20/m^3 premium is paid for chips.
- DDCL can process Eucalyptus at the same rate as pine.
- Harvester productivity will improve 40%, due to improvements in debarking.

5.8.4 Results of the NPV analysis

The results of the evaluation are given in the Table 5.17.

Table 5.17: NPV results (Rand/m³) of various systems analysed for each scenario for 2010

System	The present	Low cost scenario	Expensive scenario	Labour Intensive scenario	Mechanised scenario
	(R/m^3)	(R/m^3)	(R/m^3)	(R/m^3)	(R/m^3)
Pine Sawtimber					
System 1	38	53	326	191	74
System 2	**23**	**36**	**265**	**144**	69
System 3	29	44	382	212	**63**
System 4	38	47	425	248	72
Pine pulpwood					
System 1	82	133	744	449	216
System 2	92	139	748	473	184
System 3	67	90	**588**	**379**	96
System 4	**59**	**71**	733	501	**89**
System 5	71	96	647	477	107
***Eucalyptus* pulpwood**					
System 1	102	176	927	462	335
System 2	84	154	749	**394**	269
System 3	**73**	89	**691**	480	**115**
System 4	80	**67**	713	508	123
System 5	80	97	770	519	129
Average cost	**66**	**92**	**622**	**388**	**139**

The most attractive system under each scenario has been printed in bold, reflecting the system with the lowest cost/m^3 harvested. The R/M³ figure is obtained by dividing the total discounted cash flow amount over the six years, by the total volume removed by the system. The figures are reflected on the last line of each DCF analysis, contained in annexures 13, 14 and 15. The results of the analysis are discussed in detail in the proposed strategy for the Forestry Industry.

5.9 Development of a strategy for South Africa

5.9.1 Preferred scenarios for South Africa

The results in Table 5.17 reflect two distinct avenues for the future:

- A high road, represented by the low cost and mechanised scenarios
- A low road, represented by the expensive and labour intensive scenarios

The cost of the value chains reflected in the low road scenarios is on average 339% higher than that of the high road scenarios (an average cost of R115/m^3 vs. R505/m^3). It is thus imperative that the industry embarks on the high road to remain competitive in the global market. This can only be achieved by actively pursuing the high road scenarios through a process of capitalising on the positive change drivers and pre-empting the negative ones. This is described in more detail in paragraph 5.9.5.

5.9.2 The pine sawlog value chain

The South African sawmilling industry is currently in a survival mode. Historically, sawmills in South Africa were, generally, neither low cost producers nor differentiated. Porter (1990) described this as being "stuck in the middle". The consequences are that these mills now find it very difficult to compete in the global lumber market, due to inefficiencies and the resultant high costs. They are often outperformed by competitors who follow either a low-cost or differentiated strategy.

A transition should occur in the next decade, as mills rationalise in a geographic area in order to acquire sufficient volumes of sawlogs of the appropriate dimensions to become competitive on a low cost strategy. Smaller mills, receiving logs from the same geographic source will specialise in niche markets, thereby following a differentiated strategy (Swart, 1999). The result will be a highly competitive sawmilling industry, designed round the clustering concept (Porter, 1990). This in turn will require that forest owners be in a position to serve sawmillers with log dimensions that suit their respective niches.

Even though cut-to-length systems are still on the increase globally, tree-length systems will still dominate in the harvesting of sawlogs. The scenario analysis shows that the merchandising yard approach (System 2) will be the cheapest under the low cost scenario and the mechanised processing option will be the preferred system in the mechanised scenario. Because of the need to supply sawmills with specific log dimensions, merchandising yards will grow in popularity. Trees will be transported in the longest length possible to a merchandising yard where value optimisation will occur. The industry will achieve this through computer optimisation software, such as the electronic callipers currently used in New Zealand. Even though the cost of these instruments is relatively low, the necessity to tightly control the merchandising process will enhance the move to merchandising yards. These yards would render greater "off the shelf" sales of sawlogs and also increase customer flexibility regarding species, and log dimensions. Due to the nature of the merchandising yard system, tree-length trucks will be used to transport sawlogs. Smaller trucks will be available to move logs from the yards to smaller customers within the cluster of sawmills. However, flexibility in transport will become extremely important in keeping costs down. This could require some units that can transport both short and long logs. Transport operations require a critical mass of trucks, in order to capitalise on economies of scale. The result of the above move to merchandising yards is that hardly any sawlogs will be sold at roadside over the medium-term.

Because optimisation can also occur with the use of processors (system 3), this system could enter the sawlog harvesting market within a few years. The processor will either replace crosscutting in the merchandising yards, or the industry could revert back to a shortwood system, where the processor will merchandise logs at the landing. More stable and higher traction machines, will lead to the substitution of cable skidders with more productive grapple, and possibly, some clambunk skidders.

5.9.3 The pine pulpwood value chain

Table 5.17 shows that the DDCL system (System 4) is the cheapest for both the low cost and the mechanised scenarios. The feller buncher/grapple skidder/static delimber/slasher system (System 3) is ranked a close second for both systems. Pine pulpwood is currently predominantly harvested by CTL systems (Figure 2.20). Considering that both the attractive systems are tree-length orientated, the tree-length harvesting system will dominate the pulpwood harvesting market in 2010. The DDCL system offers significant advantages with regard to chip quality, which would increase the profitability of the pulpmills, adding a further incentive for the introduction of this system. Shortwood transport trucks will be used in conjunction with the slasher/delimber system, as pulplogs will be slashed at a landing and transported in 4,8m to 7,2m lengths to the pulpmills, depending on their requirement. The rigid truck/drawbar trailer combination will be the preferred configuration, but interlinks will still be used to a limited extent. Chips will be transported with chip truck/trailer combinations to the pulpmills.

5.9.4 The *Eucalyptus* pulpwood value chain

The results in Table 5.17 for *Eucalyptus* pulpwood reflect the inverse of those for pine pulpwood, with System 4 being the preferred system for the low cost scenario and System 3 that preferred for the mechanised scenario. The major difference in System 3 between pine pulpwood and *Eucalyptus* pulpwood is the use of a feller buncher in pine as opposed to a harvester in *Eucalyptus*. This is due to the debarking requirements of *Eucalyptus* pulpwood. Harvester heads are still in the early stages of development on the S-curve, regarding their debarking speed and quality. Even though the forecast provides for significant productivity gains for the harvester working in *Eucalyptus*, the DDCL system still proved to be marginally cheaper. As with pine pulpwood, there will be a swing from shortwood harvesting systems to tree-length systems, consisting of a combination of DDCL machines and slashers. Shortwood transport systems will be used in combination with the slashers, with a combination of the rigid truck/drawbar trailer and interlink being used. Chips will be transported with chip truck/trailer combinations to the pulpmills.

5.9.5 Actions required by the forest industry

The future actions required by the Forestry Industry to facilitate future use of the preferred Forest Engineering value chains are summarised in the form of a table, so as to allow for the identification of the relevant actions and the corresponding bodies who will be responsible for implementing those actions. Table 5.18 contains this information.

Table 5.18: Action list to facilitate future use of the preferred Forest Engineering value chains

Action	Responsibility
Systems	
Negotiate with sawmills for merchandising yard/mill delivery	Forestry companies
Negotiate with pulpmills with regard to taking in chips. Include cost-benefit analysis, similar to what has been started by Dr. Pulkki	Forestry companies
Test DDCL system in *Eucalyptus* pulpwood. Specifically check that debarking speed and quality of the machine. Determine accurate repair and maintenance figures for the machine and determine optimal chip trailer to DDCL machine ratios. Evaluate the cost of road construction required to facilitate infield DDCL systems.	Forestry companies Large contractors FESA & School of Forest Engineering
Test DDCL system in pine pulpwood. Determine accurate repair and maintenance figures for the DDCL machine and determine optimal chip trailer to DDCL machine ratios. Evaluate the cost of road construction required to facilitate infield DDCL systems.	Forestry companies Large contractors FESA & School of Forest Engineering
Test the use of the harvester/clambunk combination with slashers at roadside system in pine and *Eucalyptus* pulp. Check the debranching quality of delimbers with pulpmills.	Forestry companies Large contractors FESA & School of Forest Engineering
Introduce optimisation callipers into merchandising yards. This technology already exists in New Zealand and can be transferred to South Africa. Alternatively, the technology can be developed locally.	Sawlog producing companies FESA & School of Forest Engineering
The industry is currently in a downward spiral regarding the use of new and appropriate equipment. By extending the awarding of 3 to 5-year harvesting and transport contracts to contractors, their business risk will be reduced in purchasing new equipment and the testing of alternative systems.	Forestry companies Contractors
Stipulate the configuration of equipment to be used in contracts. The results of this study can be used as a basis on which to conduct a detailed study to determine to optimal system for the particular contract area.	Forestry companies Large contractors
Revise tertiary education curriculum to reflect global harvesting trends. This study clearly shows the global skills that a harvesting forester and harvesting contractor will require in the future. It is important to build the Forest Engineering curriculum around these requirements and to teach towards them.	FESA & School of Forest Engineering
Implement the use of the Forest Engineering unit standards, as developed by FESA for the NQF throughout the industry. Ensure that forestry companies and contractors only employ workers who have the required qualifications and/or unit standards.	Training centres Forestry companies Contractors Trade Unions
Support the development and accreditation of forestry training centres throughout the country. This should include the establishment of at least one training centre focussing on the training of machine operators, being capable of providing training for the equipment in the future value chains identified in this study. The development of true partnerships between training centres and forestry companies/contractors are required to achieve success in operator performance.	Training centres Forestry companies Contractors Trade Unions
The Industry must develop a co-operative HIV/AIDS prevention and treatment program, along the lines proposed by Whiteside and Sunter (2000).	Government Forestry South Africa Contractors Trade Unions
Equipment suppliers to investigate the option of renting out all harvesting equipment, thereby facilitating the introduction of new technology by contractors and forestry companies	Equipment suppliers Contractors Forestry companies
Negotiate with certification bodies to use multi-disciplinary teams in their auditing process. This is commonly the approach overseas and will assist in achieving an objective audit	Forestry companies Forestry South Africa
The Industry is to continue lobbying with Government to expand the diesel rebate to contractors	Forestry South Africa
The Industry should make international equipment suppliers aware of its intention to manage towards the preferred scenarios and to gain their support in introducing the relevant equipment requirements reflected in the preferred value chains.	Equipment suppliers Contractors Forestry companies
For operators to be motivated and competent, they will have to be rewarded for productive work through an acceptable (and competitive) wage level and the use of incentive systems.	Forestry companies Contractors Trade Unions
There is a need to understand the capabilities of the equipment they use. This requires the development and implementation of a comprehensive set of Forest Engineering BOP's with which targets can be set and the results compared.	Forestry companies Contractors

5.10 Future machine numbers in South Africa

The forecast only includes a forecast of the machines that will be used in commercial plantations.

The machine number forecast is based on the following assumptions:

- Mechanised ground skidding systems are used on slopes of 35% and less;
- Cable yarding systems are used on slopes greater than 35%;
- The percentage usage of ground skidding and cable yarding will remain at 93% and 7% respectively;
- 76% of the plantation area will remain with corporate forestry owners.

5.10.1 Industrial forestry annual cut

The total annual cut forecast for the South African Forestry Industry in 2010, as forecast by Godsmark (2001) is given in Table 5.19:

Table 5.19: Total annual cut forecast for 2010

Softwood	10 082 000m³
Hardwood	12 872 000m³
Total	22 954 000 m³

This volume is reduced accordingly for ground skidding. Table 1.4 shows that 93% of the total afforested area in South Africa is suited to ground skidding.
The 22 954 000 m³ is thus reduced to 21 347 220 m³.
Industrial forests will contribute 76% of the total annual cut in South Africa, producing 16 223 887 m³ of roundwood.

5.10.2 Number of ground skidding machines in 2010

The annual capacities for the various machines are based on the system capacities given in Annexures 13, 14 and 15. The machines/equipment required for the most profitable system are then used to calculate the total number of machines expected to operate in the industrial sector in 2010. Table 5.20 reflects these results.

Table 5.20: Number of machines in the industrial forestry sector of South Africa in 2010

Machine type	Low cost scenario	Expensive scenario	Labour intensive scenario	Mechanised scenario	Average Low road scenario	Average High road scenario
Feller buncher C&B	53	100	80	53	90	53
Feller buncher disk	171	0	160	376	80	274
Large processor	0	0	0	107	0	53
Harvester		640	0	282	320	141
Chainsaw	480	700	1920	0	1310	240
Grapple skidder	450	520	480	295	500	372
Clambunk skidder	0	480	0	282	240	141
Forwarder	0	0	480	0	240	0
Loader	107	1000	1040	348	1020	227
3 Wheeler	213	200	320	0	260	107
Front end loader	107	200	160	107	180	107
DDCL	171	0	0	94	0	133
Loader/delimber/slasher	0	480	480	0	480	0
Loader/slasher	0	0	320	188	160	94
Rigid drawbar	0	2720	2400	753	2560	376
Chip trucks	1703	0	0	847	0	1275
Stinger steer	267	500	480	0	490	133
6X4 trucks	0	0	0	747	0	373

The South African Forestry Industry should plan to reach the high road scenario. It is therefore appropriate to discuss only the machine population in 2010 for this scenario. The results of the machine population for 1987 and 1997, obtained from the Forest Technical Surveys (Chapter 2), are compared to those of the high road scenario in Table 5.21.

Table 5.21: Comparison of the results of past machine populations with the 2010 forecast

Machine type	1987	1997	Forecast 2010
Feller buncher	13	32	327
Large processor	0	0	53
Harvester	0	3	141
Chainsaw	5000	4000	240
Grapple skidder	1	18	372
Clambunk skidder	0	0	141
Forwarder	59	34	0
Loader	N/A	N/A	227
3 Wheeler	326	538	107
Front end loader	42	66	107
DDCL	0	0	133
Loader/delimber/slasher	2	4	0
Loader/slasher	0	0	94
Rigid drawbar	N/A	N/A	376
Chip trucks	0	0	1275
Stinger steer	0	15	133
6X4 trucks	217	206	373

Table 5.21 reflects a general swing to mechanisation for the harvesting of pine sawtimber, pine pulpwood and *Eucalyptus* pulpwood. There are sharp increases in the number of feller bunchers and grapple skidders, at the expense of chainsaws and cable skidders. Over time, more chainsaws could be replaced with the advent of large processors, used to merchandise at the landing or at a merchandising yard. The system evaluation assumed that front-end loaders would be used in the merchandising yards, to sort and stack timber, in conjunction with 3-wheeled loaders, hence, the high number of these machines forecast in 2010. Furthermore, when configuring the various systems, it was assumed that 3-wheelers will be replaced by excavator-type loaders infield. This is based on the potential environmental impacts of 3-wheelers and the fact that excavator-type loaders have proved themselves in various forestry applications in the country (personal observation).

The chainsaws generally used for the harvesting of pine pulpwood, in combination with tractor and trailer units, will also be replaced with the feller buncher/grapple skidder combination. The full trees will then either be chipped at roadside, or cut into pulp logs with a delimber/slasher combination.

The systems for the harvesting of *Eucalyptus* pulpwood are very similar to that of pine pulpwood, except that harvesters will be used to debark pulplogs, working in combination with clambunk skidders. Chipping will also be common, where pulpmills are willing to accept chips in lieu of logs, hence the large number of DDCL machines forecast for 2010.

In conclusion, the forecast shows a dominance of the TL systems in South African industrial forestry in the future. CTL systems and traditional systems will continue to have limited application, where geographic and volume constraints prohibit the use of the high-volume, mechanised TL systems.

5.10.3 Cable yarding

Only 7% of the total timber volume (Table 1.4) will be extracted by cable yarders in 2010, amounting to 1 606 780 m³ per year. Table 5.22 summarises the product distribution of the annual cut.

Table 5.22: Forecast of annual cut extracted by cable yarders in 2010 by product

Product	Annual volume
Sawtimber	642 712 m³
Pulpwood	964 068 m³
Total	**1 606 780 m³**

Table 5.23 gives the productivity figures for cable yarding, based on SAFCOL (2000).

Table 5.23: Productivity figures for cable yarders in 2010 (SAFCOL 2000)

Product	Yarder size	Daily production (m³)	Annual production (m³)
Sawtimber	Medium	80	17 680
Pulpwood	Small to medium	40	8 840

The number of machines forecast for 2010, based on the above figures is given in Table 5.24:

Table 5.24: Forecast of the number of cable yarders in 2010

Yarder type	Number of machines
Medium	36
Small to medium	109
Total	**145**

The total current cable yarder population in South Africa is 93 machines (Figure 2.26). A significant increase (56%) can thus be expected in the number of cable yarders over the next decade.

5.11 Conclusion

The use of the forecasting method to forecast the South African Forest Engineering value chain gives a satisfactory result. It has been clearly demonstrated that the chronology of the steps in the method are sound. It is also clear that the forecasting techniques proposed within each step are both appropriate and valid. The application of the forecasting method has also resulted in the development of a costing system, which allows for the ranking of alternative harvesting and transport systems with regard to their cost effectiveness. The NPV method in DCF analysis is used in the costing system.

The proposed forecasting method can therefore be practically applied, as it has been proposed in Chapter 4.

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The purpose of the study is to test the following hypothesis:

The null hypothesis for this study is:

H_0 : As a result of the development of a forecasting method, unique to the Forest Engineering value chain, the systems in the future Forest Engineering value chain cannot be forecast for South Africa in the year 2010.

This is tested against the alternative hypothesis:

H_A : As a result of the development of a forecasting method, unique to the Forest Engineering value chain, the future systems in the Forest Engineering value chain can be forecast for South Africa in the year 2010.

The results of the study substantiate the alternative hypothesis of the study, namely that the development of a forecasting method, unique to the Forest Engineering value chain, allows for forecasting of the future South African Forest Engineering value chain.

It was necessary to have a sound point of departure, to allow for a point of reference for the future. The FTS, discussed in Chapter 2, provides this. The FTS gives a comprehensive *status quo* of labour, harvesting systems, transport systems and forest roads in South Africa.

Forest Engineering systems are a function of global environments in this field, hence the importance of the global historical developments in forest engineering and related fields. Without the literature overview given in this regard in Chapter 2, it wouldn't have been possible to gauge the relative position of South Africa to those of the rest of the world. More importantly, Chapter 2 clearly demonstrates that harvesting and transport systems are primarily technology driven, and that South Africa will remain primarily a consumer of harvesting and transport technology, as opposed to a producer thereof.

This led to the necessity to gain a comprehensive understanding of technology, the management thereof and how technology strategies are to be developed and implemented, as discussed in Chapter 3. After giving a comprehensive background of technology, the chapter continues in analysing forecasting and costing techniques, which could be relevant in the development of the forecasting method. The techniques that are discussed were carefully selected, based on the understanding gained of the Forest Engineering value chain and the overview of technology.

The crux of the study then culminates in Chapter 4, where, through a process of analysis and creativity, the potential forecasting and costing techniques converge into a logical process to form a unique method to forecast future systems in the Forest Engineering value chain. This includes a flow chart of the steps required in the forecast, as well as a detailed description of why a specific technique was selected and how it is to be applied. This study is based on a multi-disciplinary approach in forecasting the future – an approach that has not been used before. It combines various disciplines into a powerful tool to allow for the development of robust strategies to meet the demands of the future. These are:

- timber harvesting machine costing techniques
- transport costing techniques
- financial analysis techniques
- technology forecasting techniques
- techniques used in the business world to plan for the future
- strategic planning techniques

As the forecasting method is based solely on theory, it was necessary to validate the use thereof, as reflected in Chapter 5. The forecasting method, developed in Chapter 4, is used to forecast various Forest Engineering value chains for the South African Forestry Industry. The application of the model allowed for the assimilation of a substantial amount of new evidence in the field of Forest Engineering. Examples of this are given below:

- The Delphi technique was used to identify past and future change drivers in timber harvesting and transport, a forecast of global harvesting systems in 2010, the position of contracting out of timber harvesting in 2010 and the skills required of harvesting foresters and contractors in 2010.
- It was determined what the level of substitution will be by 2010, of TL systems by CTL systems, and DTT machines by STT machines. This was achieved by using the Fisher-Pry substitution curve technique.
- A detailed scenario building exercise was completed, thus applying the normative form of forecasting. This approach accepts that the future is not deterministic and that alternative views of it are possible, thus allowing a grasp of how uncertainty about different forces can lead to very different futures. This culminated in the identification of two factors, which are influenced by all change drivers, namely the cost of labour and the cost of machines.
- It was necessary to develop a costing system, which would allow for the ranking of alternative value chains under each scenario, with regard to their cost-effectiveness. This required an interpretation of the various approaches discussed in Chapter 3, and the application thereof within the context of the Forest Engineering value chain forecast, for each of the relevant scenarios. The costing model that was developed is unique in the sense that it combines the time value of money (NPV) with traditional costing systems used in timber harvesting and transport analyses, and also allows for the quick modification of input variables, for the analysis of systems for the various scenarios.
- A summary of the necessary strategies is then given, which the Forestry Industry to follow, to allow for the development of the preferred scenarios. Without the effective implementation of the findings of the study, its value will be lost to the Industry.
- Chapter 5 concludes with a summary of the forecast of the various machine-type populations for 2010. This information is of great value to machine suppliers, who need to plan for the future potential market.

6.2 Recommendations

At the conclusion of the study, certain questions have been generated, which have not been fully answered. The most important, of which are summarised below:

- The forecasting method can comfortably be applied to any other region or country in the world. However, it is not clear what the optimal time frame for such a forecast should be. With the continuous increase in the speed of the development of technology, it would be useful to validate the best time frame for a forecast.
- Further work needs to be done on the substitution of TL systems by CTL systems. The historic data used in this study was insufficient to gain a reliable curve in this regard.
- The scenario analysis resulted in identifying two factors around which future scenarios are built, namely the dominant cost of labour and the dominant cost of machines. It can be expected that these would be the same two factors relevant to a forecast elsewhere in the world, but needs further investigation to be validated as such.
- It was assumed in the analysis of the pine sawtimber systems, that truck/ trailer combinations will not be used for the transportation of logs. As transport systems develop, this assumption could be proven wrong.
- Because of the international focus on the mechanised debarking of *Eucalyptus*, it was assumed that harvester productivity will increase by 40% by 2010. More work needs to be done in this regard, to substantiate more reliable productivity trends for these machines.

Other recommendations are:

- It is important to maintain continuity of the FTS. It is therefore recommended that the FTS be repeated in 2007, 10 years after the previous.
- The use of the forecasting model in other parts of the world could lead to refinements in the application thereof. It is recommended that the model be used for similar forecasts in order to continue improving the method applied.
- The findings of the study are only as useful as the implementation thereof. It is recommended that the South African Forestry Industry take full ownership

- The findings of the study are only as useful as the implementation thereof. It is recommended that the South African Forestry Industry take full ownership of the results, refine the proposed strategies and thereby contribute to a thriving industry in the future.

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